Geograpic Studies Series (10)

Topics on the ENVIRONMENTAL GEOGRAPHY of Sudan

Prof. Samir Mohammed Ali Hassan Alredaisy

First edition
2024 AD

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دار آريثيريا للنشر والتوزيع
Arrythria for Publishing and Distribution

الناشر
دار آريثيريا للنشر والتوزيع – الخرطوم – الســودان
جوال: 00249122094856 - 121566207
البريد لإلكتروني: arithriaforpublishing@gmail.com

تاريخ النشر:
الطبعة الأولى – 2024م

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Introduction

Sudan faces many serious environmental challenges and problems where geography could contribute to the mitigation of their impacts. Environmental geography is an applied field that deals with environmental issues, challenges, and problems. This book is concerned with some such aspects where many topics were included. They include topics of ecological benefits of bioremediation of oil contaminated water in rich savannah of Palogue, Upper Nile Area-Southern Sudan; ecological impacts of mesquite prosopis spp. expansion in Toker Delta, northeastern Sudan; climate change and environmental impacts in Sudan; ecosystem of Red Sea Basin and threststs; anthropogenic factors exacerbating high siltation and mesquite expansion in Toker Delta in eastern Sudan; challenges of rapid urbanization to squatter settlements in Greater Khartoum, the case of Dar El-Salam El-Magharba in East Nile Locality; environmental and poverty implications with traditional tanning in Omdurman; socioeconomic and environmental implications of traditional gold mining in Barber Locality, River Nile state, Sudan; deterioration of acacia in western Butana plain, Sudan; vegetation dynamic in western Butana plain, Sudan; development of wastes disposal management In Khartoum area within challenges of urban growth during the period 1998-2013; and natural components of mountain tourism in the Sablouqa region,Nile River State - Sudan

These topics on the environmental geography of Sudan satisfy the objective of this book which is to review and discuss these topics as imperatively significant and important for environmental management and planning in Sudan and furthermore, to work towards alleviating their negative impacts. It is important to recommend for future writings on medical geography of Sudan by authorized researchers..

Samir Mohamed Ali Hassan Alredaisy
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March 2024

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Ecological benefits of Bioremediation of Oil Contaminated Water in Rich Savannah of Palogue, Upper Nile Area-Southern Sudan

1

Ecological benefits of Bioremediation of Oil Contaminated Water in Rich Savannah of Palogue, Upper Nile Area-Southern Sudan

Oil is used worldwide as the main source for energy. It threatens the natural environment as its composition is made of complex molecules, when burned produces relatively high levels of carbon dioxide, sulfur dioxide and nitrogen oxides (table 1). Global warming, the increase of average world temperatures as a result of the greenhouse effect, is one of the impacts of oil using. Carbon dioxide contributes by about 50% to the greenhouse effect, in addition to methane, chlorofluorocarbons and nitrous oxide (www.ypte.org.uk, 2010).. Greenhouse effect could lead to a rise in average global temperatures between 1.5 - 4.5 C^0 as early as the year 2030 (www.ypte.org.uk, 2010).

Table (1): Sources and total discharged/ year of oil in North America and Worldwide

source of oil	tons discharched per year, North America	% of total	tons discharched per year, worldwide	% of total
Petroleum Extraction	2,980	3%	38,160	6%
Oil platforms	160	0%	860	0%
Water produced during operations	2,700	3%	36,000	5%
Other	120	0%	1,300	0%
Transportation	9,100	10%	153,300	23%
Pipeline spills	1,900	2%	12,000	2%
Vessel spills	5,300	6%	100,000	15%
Other	1,900	2%	41,300	6%
Petroleum Consumption	83,500	87%	476,600	71%
Land-based and stormwater runoff	54,000	56%	140,000	21%
Recreational watercraft	5,600	6%	N/A	N/A
Spills	1,200	1%	7,100	1%
Other	22,700	24%	329,500	49%
Total human-caused discharges	95,580	100%	668,060	100%

Source: National Academy of Science, USA (2010).

This is in addition to droughts where continental heartlands will dry out more in summer and floods as sea levels are already rising at a rate of 1 to 2mm each year due to expansion of the top layer of the oceans as they warm and the melting of the polar ice caps (www.ypte.org.uk,2010). Habitat destruction from drilling, pipelines and processing facilities and air pollution from petroleum emissions before being burned as fuel are also environmental impacts associated with oil. Here, forest clearance and wood burning is adding to the CO_2 in the atmosphere as that area of the Amazon rain forest which was burned, adding 500 million tones of CO_2 to the atmosphere (www.ypte.org.uk,2010). Also the land taken up by all of the wells, pipelines, roads, processing plants and other facilities needed to remove oil from the ground and turn it into commercial products. The processes of oil exploration and production produce many wastes which are no longer used for their original purpose and requires disposal. Oilfield Wastes include used lubricants, filters, waste oil, sludge, etc. Such wastes are hazardous to people, property and the environment and should be managed properly. Concerning ocean pollution, only 12% of the oil that enters the oceans comes from tanker accidents; while over 70% of oil pollution at sea comes from routine shipping and from the oil people pour down drains on land. Here, heat increases temperature that results in the deaths of many aquatic organisms, several billion salmon and herring eggs are also believed to have been destroyed (Krantz and Kifferstein, 2010). Petroleum often pollutes water bodies in the form of oil, resulting from oil spills.

Crude oil naturally contains fossil water which chemically contains Hydrocarbons which need to be cut. Some electrical and mechanical methods are available but, they pose environmental problems to let bioremediation more advantageous. Natural bioremediation has been occurring for millions of years such as that of dead vegetation and animals. Chemical energy presents in waste materials change to active microorganisms to grow while they convert organic carbon and hydrogen to carbon dioxide and water. Generally bioremediation is the optimization of the natural biodegradation process. It causes microorganisms, fungi, green plants or their enzymes to remove toxic hydrocarbons from the environment to return it to its original condition. Crude petroleum and petroleum products are degraded by contact with the microorganism under certain conditions (table 2). The microorganism and enzymatic active material are effective for degradation in inhospitable climates and various land and open water conditions, generate no deleterious products or chemicals, and are long-acting and rapid in onset of initial activity (United States Patent 4415661).

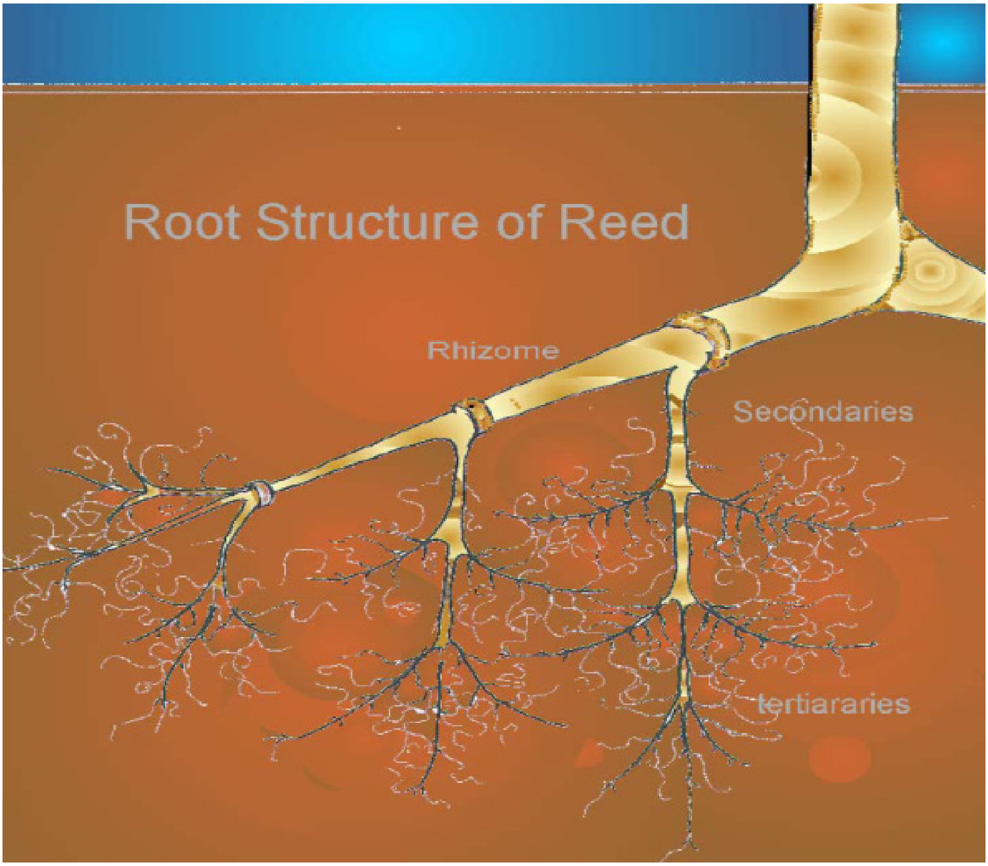
Table (2): Essentials factors for microbial bioremediation

Factor	Desired Conditions
Microbial population	Suitable kinds of organisms that can biodegrade all of the contaminants
Oxygen	Enough to support aerobic biodegradation (about 2% oxygen in the gas phase or 0.4 mg/liter in the soil water)
Water	Soil moisture should be from 50-70% of the water holding capacity of the soil
Nutrients	Nitrogen, phosphorus, sulfur, and other nutrients to support good microbial growth
Temperature	Appropriate temperatures for microbial growth (0–40˚C)
pH	Best range is from 6.5 to 7.5

Source: Advameg.Inc.(2010)

Certain plants are able to extract hazardous substances such as arsenic, lead and uranium from soil and water. This is known by phytoremediation which achieves the conditions necessary to facilitate the breakdown of contaminants. Wetland plants, such as Reeds Beds ''Phragmites australis'' (figure 1) are capable to do that. Reeds Beds root structure composes rhizome, secondaries and tertiaries rootlets. Rhizome is a thick horizontal underground stem whose buds develop new roots and shoots of secondaries and tertiaries. Through this roots structure Phragmites australis transfer atmospheric oxygen down in order to survive in waterlogged conditions. This creates a healthier soil environment with pockets of both aerobic and anaerobic activity which breakdown the hydrocarbon sequence of oil contaminated water and releasing CO_2 into the atmosphere. Phragmites australis naturally accumulates high levels of cadmium and zinc from the environment similar to sunflowers which were also used to clean up uranium. Phytoremediation-related processes can change the location or chemical makeup of contaminants (Elizabeth and Freeman, 2006).

Figure (1): Root structure of Reed Beds "Phragmites australis"



Source: Petrodar Oil Operation Company (2010)

Studying the interaction between plants and microorganisms during petroleum-hydrocarbon bioremediation in Pacific islands coastal soils, found that an increase in the grading populations' size of the hydrocarbon-degrading populations of microbes, elicited by rhizodeposition, is generally regarded as conducive to an enhanced degradation of petroleum hydrocarbon pollutants in vegetated soil (Jones, 2004). The process of bioremediation can be monitored indirectly by measuring the oxidation reduction potential or redox in soil and groundwater, together with pH, temperature, oxygen content, electron acceptor/donor concentrations, and concentration of breakdown products such as carbon dioxide (table 3).

The treatment of environmental pollution by bioremediation is a promising technology, having the potential to treat contaminated material at the site or to remove contaminated material to be treated elsewhere. Some examples of bioremediation technologies are bioventing, land farming, bioreactor, composting, bioaugmentation, rhizofiltration, and biostimulation (Wikipedia, 2010). Various genetic approaches have been developed worldwide to optimize enzymes, metabolic pathways of organisms and plants relevant for biodegradation (Pieper, 2000). Although most organisms have detoxification abilities (mineralization, transformation and/or immobilization of pollutants), microorganisms play a crucial role in biogeochemical cycles and in sustainable development of the biosphere (Asatiani, 2004).

Table (3): The decreasing biological breakdown rate as function of the redox potential

Process	Reaction	Redox potential (E_h in mV)
Aerobic:	$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$	600 ~ 400
Denitrification	$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O$	500 ~ 200
Manganese IV reduction	$MnO_2 + 2e^- + 4H^+ \rightarrow Mn^{2+} + 2H_2O$	400 ~ 200
Iron III reduction	$Fe(OH)_3 + e^- + 3H^+ \rightarrow Fe^{2+} + 3H_2O$	300 ~ 100
Sulfate reduction	$SO_4^{2-} + 8e^- + 10H^+ \rightarrow H_2S + 4H_2O$	0 ~ −150
Fermentation	$2CH_2O \rightarrow CO_2 + CH_4$	−150 ~ −220

Source: Wikipedia, the free encyclopedia (2010)

Bioremediation can occur on its own (natural attenuation or intrinsic bioremediation) or can be spurred on via the addition of fertilizers to increase the bioavailability within the medium (biostimulation). Recent advancements have also proven successful via the addition of matched microbe strains to the medium to enhance the resident microbe population's ability to break down contaminants ''bioaugmentation'' (www.pollutionsissues.com, 2010). Bioremediation technologies are also applied to contaminated wastewater, ground or surface waters, soils, sediments and air where there has been either accidental or intentional release of pollutants or chemicals that pose a risk to human, animal or ecosystem health. Different approaches to bioremediation take advantage of the metabolic processes of different organisms for degradation, or sequestering and concentration, of different contaminants (Theresa Phillips, 2010).

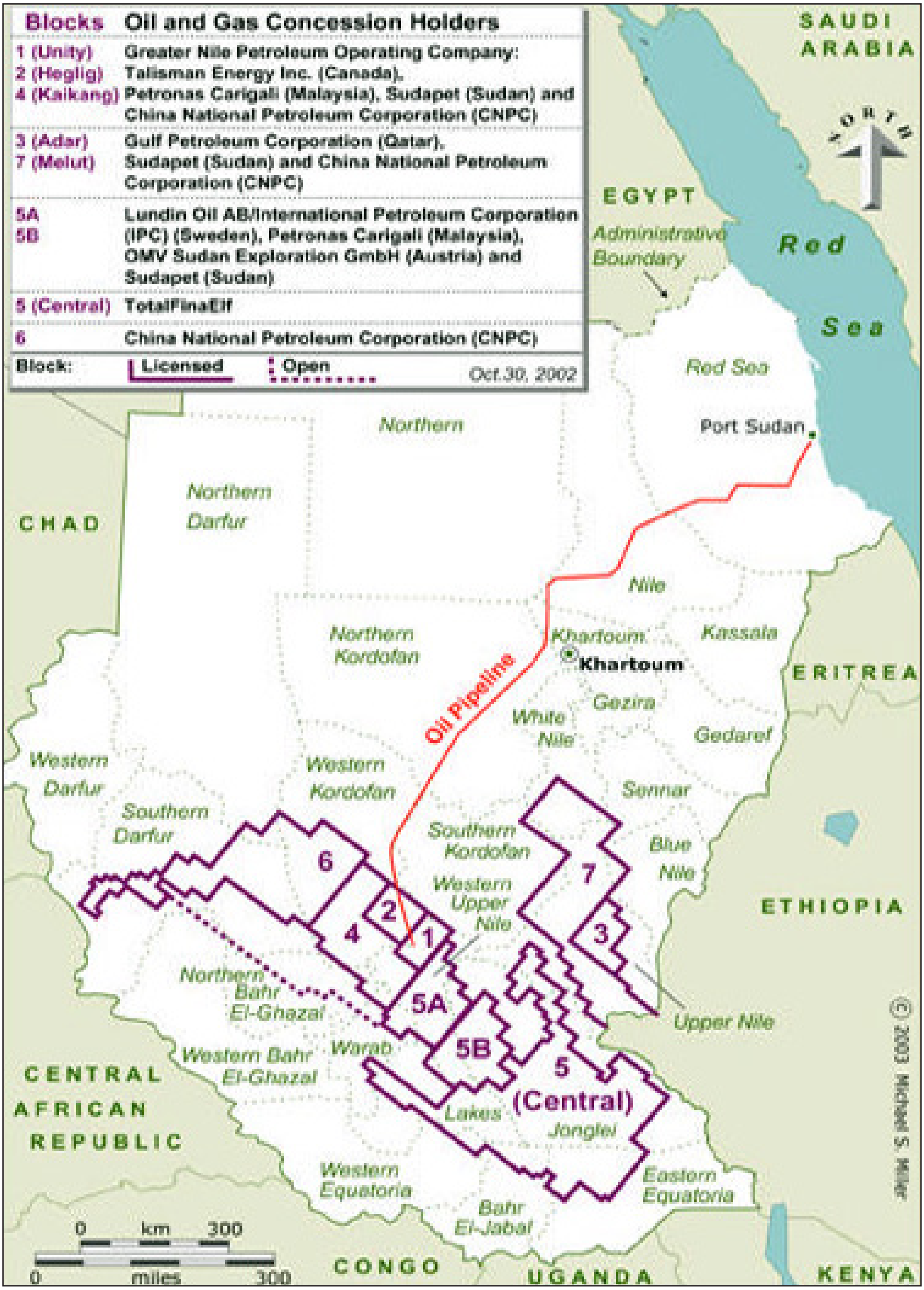
Data and methodology:

Sedimentary basins of Sudan hold oil. First oil explorations started in 1959 in the Red sea area by Chevron Oil Company which was also allocated 516,000 km^2 into the interior southwestern and southeastern basins of Sudan. In 1981, oil explorations started widely and many oil companies such as GNPOC; WNPOC; CNPC; PDOC, SUDAPET hold concessions of oil exploration and production in the country (figure 2). Petrodar Oil Operating Company (PDOC) holds oil concession in Palogue, blocks 3 and 7 (figure 2). By now there are 180 operating oil wells distributed within Palogue, Molaita, A'adar, and Gimri oil fields all are linked with an export terminal near Port Sudan.

Rich savannah environment of Upper Nile area allowed for ecological diversity. Annual rainfall amounts to 700 mm and soils are black clayey supporting rich savannah forests, grasses, wild animals and possibilities for animal ranching. However, following World War 2, short staple cotton and Dura (sorghum vulgare) were introduced into areas along and nearby the White Nile River. Irrigated and rained based agricultural schemes had extended form Dabat el Fukhar in the far north to Malout and Khor A'adar in the far south, now producing oil. Grazing areas outside el Gaigar were allocated for groundnuts production while animal hunting was profitable. But, due to civil war in southern Sudan It was severely affected by desertification, deforestation and decreasing wild animals. The main objective of this paper is to highlight the importance of bioremediation of oil contaminated water as a tool to compensate for such an environmental degradation.

The fieldwork was conducted during 12-14 February 2010 in Palouge oil fields in the Upper Nile area of southern Sudan. The data was collected by direct interviewing with field engineers, laboratory technicians, and representatives of the Dutch Company managing the project, field managers, field officers, and safety engineers as well as relevant office data. The whole processes of oil exploration, production and bioremediation of oil water by Reed Beds (Phragmites australis) were investigated. 90% of oil contaminated water was cut. The remaining 10% goes with the crude oil to el Jabalein Central Processing Facility (CPF) where 9.5% of water is cut there, while the remaining 0.5% is accepted in oil marketing. El Jabalein Central Processing Facility (CPF) was visited during 17-19 February 2010; its results were not included here as oil water is still below the level to introduce Reed Beds.

Figure (2): Location of the study area (blocks 3 & 7)



Source: Ministry of Power and Mining, Sudan (2009)

Bioremediation of oil water:

Palogue's oil fields produce 300,000 oil barrels/ day (figure 3). These amounts were received into the oil gathering manifold (OGM), consisting of 13 main units. From thereafter, the crude is processed into the Field Processing Facility (FPF) to cut water. This produces around 133,000 barrel of water/ day, from which 16000 barrels were injected back into oil wells to facilitate drilling while the remaining 114000 barrels of water are bioremediated. Bioremediation starts (figure 4) by the flowing of contaminated oil water into the barrow bits (3 bits) and then by gravity water flows to the lagoons (6 lagoons, see photo. 1). Through valves, water then goes to the Reed Beds area (9 divisions) where bioremediation takes place. Lastly, the bioremediated water is transferred through channels into the forest area. A Reed bed is brought from Um Dom area in southeast Khartoum north town.

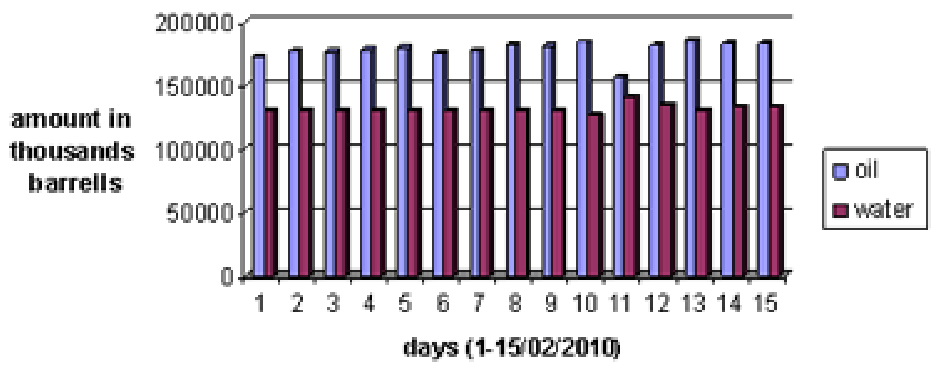
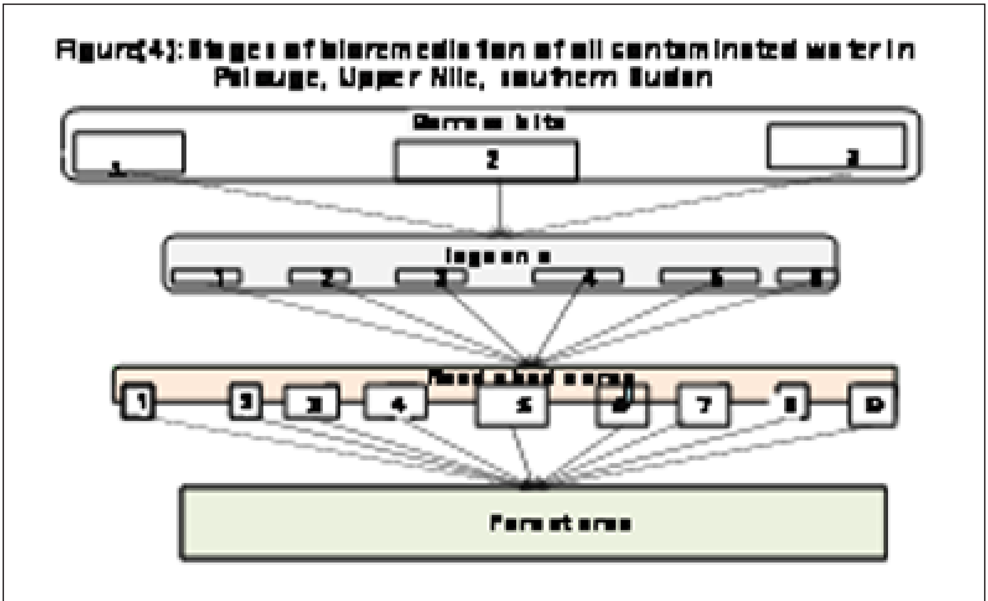


Figure (3): Oil and oil water production in Palogue for the period 1-15 February 2010
source: Fieldwork, Palogue 2010



Ecological benefits of bioremediation in Palogue:

The use of Reed Beds had succeeded to dissolve contaminants to enable oil water discharge to the Palogue's environment to prevent environmental pollution. Ecological benefits of this produced oil treated water are many, among which are improving local biodiversity with the addition of a constructed wetland (photo. 1), the increase in key resources such as food and water which created a dramatic boost in ecological diversity. This impressive improvement to the immediate ecosystem is evident with common bird species. Photo (1) depicts a huge lagoon of bioremediated oil water. On the far side of the photo there is an extending line showing the outside limit of the forest area where trees can be noticed. This constructed water body will, of course, be good enough for attracting birds and animals and growth of trees all of which can allow for biodiversity.

Bioremediation water quality criteria for irrigation of the forest area in Palogue, is judged versus FAO standards or guidelines. Chloride (Cl), boron (B), trace Elements, nitrogen (NO_3 – N) and pH impose no restriction on use of water for irrigation while for bicarbonate (HCO_{3-}), It is important only if sprinkler irrigation system is used. The fieldwork results indicate that aqueous solubility, the octanol-water partition coefficient, and organic carbon content of the soil are affecting the contaminant concentration in the water phase. For livestock water quality criteria, salinity requirements for irrigation are more restrictive than those for animals but highly saline water or water containing toxic elements may be hazardous to animal health and may even render the milk or meat unfit for consumption. According to field engineers in Palogue, the bioremediated water can be rated as very satisfactory for the use by livestock and can also be usable for all classes of poultry.

Photo. (1): Lagoons for oil contaminated water in Palogue

Downstream implications once verified as clean, all water are released to the environment. It is immediately used for forestry or bio-fuels only after a toxicology testing program verified the water as suitable for forestry plantation. This situation is supported by some tropical trees like which have significantly accelerated the degradation of petroleum hydrocarbons in coastal tropical soils (Sun, 2004). After forestation phase, such water can be used further for other purposes in Palogue.

Improvement in local biodiversity in downstream is beneficial use for local community in Palogue. Typical water requirements per hectare (1 feddan = 1.038 acres= 0.42 hectares) are that water/hectare for grass is 1.0080 m3 /day, cereal is 1.2096 m3 /day, charcoal crop (referring to tree species that were burnt to produce charcoal) is 0.8568 m^3 /day, mahogany, water melon, and cucumber is 1.35105 m^3 /day, forestry area water use with cereal and vegetable crop is 58.8 km^3 /day, forestry area water use with tree crop is 41.0 km^3 /day, irrigation of cereal forestry requires additional 1mm rainfall /day, irrigation of tree forestry creates 2.5 mm standing water / day. Water requirement is seasonal and can be managed for rotational crop use and proper irrigation can potentially produce up to 4 times the output of rainfall irrigated agriculture (Fieldwork, 2010). Also, Windsor bean, herbaceous legume reaching 30 - 180 cm in height and annual vigorous tap root provides groundcover in 55-90 days will outgrow any residual vegetation reach a stage ready to be ploughed into the soil before natural vegetation reaches seeding stage. Toxicology ensure that there is no toxicological problem with crops grown from produced water and testing cereal, fruit, vegetables, fodder, nuts, animals, eggs & milk, and fish within 18 months growing and testing crops to ensure safe human and animal consumption. According to Hunag and Takeuchi (2005) the sustainable development of an oasis-style ecological and economic system, making good use of the water resource of northwestern China, is suggested to develop the aquaculture. In addition, integrating aquaculture in lakes and reservoirs (culturing Chinese domestic fishes as well as other aquatic species) with agriculture on the arid lands near lakes and reservoirs will contribute to the bioremediation of the arid ecosystem, to the improvement of the biological diversity, and to the stabilization of an oasis ecosystem of Jiuquan City and its surrounding areas. Moreover, the development of aquaculture and plantation can result in not only economic and ecological benefits, but also profound changes to the industrial structure of Jiuquan City.

Naturally occurring bioremediation and phytoremediation have been used for desalination of agricultural land by phytoextraction which has a long tradition. This depends on using some plants having the potentiality to extract salt from agricultural soils used for long periods of time. When bioremediation is applied by people, microbial biodegradation processes are said to be managed, one example is land farming by managing biodegradation of organic compounds that are distributed onto the soil surface, fertilized, and then tilling. The proposed fallow crop by remediated water in Palogue is applied for initial crops. This will improve soil water retention ability, regulates alkalinity, adds nutrients and reduces phytotoxic effects. The study on phytotoxic effects on the growth of red beans (Phaseolus nipponesis) and corn (Zea mays) showed that bioremediation with Nocardia sp. H17-1 reduced phytotoxicity more in corn than in red bean, suggesting that this microbial species might degrade PAHs to some degree (Bake, 2004). The biodegradation of PAHs in soils can be enhanced by employing surface-active agents. These results indicate that SL and HS are biodegradable and efficiently enhance PAH bioavailability in soil. These natural surfactants significantly intensified the aerobic bioremediation of a historically PAH-contaminated soil under treatment conditions similar to those commonly employed in large-scale soil bioremediation (Fava, 2004).The seed germination and the activities of the assayed enzymes, amylase and protease, were same as before or better in bioremediated soils (Bidlan, 2004).The research is going on crops used as fodder to test animals and animal products in Palogue.

Soil in Palogue is predominantly black cotton clay and its chemical composition included calcium bicarbonate, hence requires improvement with nitrification and addition of acid balancing organic matter. Phytoremediation has the potential to enhance soil improvement and thus clean up soil from unwanted elements. Also for soil pollution treatment, a study on the possibility of hydrogen peroxide pretreatment and plant system to remediate soil pollution in Fuyang County in China showed that H2O2 could enhance the availability of Cu and Zn in soil and planting with Ryegrass influenced the behavior of pollutants in soil (Sung, 2004). By means of the biostimulation and bioaugmentation in the micro-ecological environment of contaminated soil with petrochemical hydrocarbons, the biodegradation rates and mode of the contaminants were significantly improved (Jia, 2004). In addition, the use of calcium peroxide provided oxygen for contaminant biodegradation in a saturated soil (Cassidy, 1999). However, phytoremediation indirectly improve soil quality by improving soil structure (aggregates and peds) and increase porosity/ aggregation and therefore water infiltration, providing nutrients (nitrogen – fixing legumes) accelerate nutrients cycling and increasing soil organic carbon (Schnoor et al., 1995; Cunningham, 1996). The growth of certain hardy plants in a contaminated soil can allow the growth of the other less hardy plants. Cunningham (1996) indicated that a tolerant grass species (Vetiveria zizanioides) thrived in the clay soil contaminated with up to 3% of total petroleum hydrocarbons. The same soil was initially extremely phytotoxic to a variety of crop plants tested.

In Palogue oil fields, it is expected that with the addition of a constructed wetland (photo. 1), evapo- transpiration rates will rise considerably to allow for precipitation; possibility for compensation for forests cutting for oil investment, and prospects for future forestation and better human occupancy in the area. Of course, these will ultimately provide natural assets for agri. - related activities, where for example, the fishing community is flourishing in Palogue and similarly in Higlieg, an oil field belonging to GNPOC Oil Company in block 1(figure 2).

In Palogue, higher evaporation rates due to high rates of heating during summer and considerably average temperature does not fall below 35 ^{0}C during winter, the climate of closer areas to water ponds recorded lesser temperatures by 3 Celsius degrees compared to far areas from water ponds.

A negative ecological impact of oil production in Palogue is the emission of oil gases which amounted 40000 M^3/day including H_2S, CO_2, CO, C (fieldwork, 2010). These gases were burnt in situ and by so might raise local temperature of the neighborhood and increases vulnerability to respiratory diseases. Records by Palogue Clinic depicted that respiratory diseases made up 17.44% of total of diseases during 2008 (Palogue Clinic, monthly report, April 2009). But, such gas emissions, if properly treated, can generate a heating source for tapped water in the employees' camps during winter season or for other related human needs. Here, phytoremediation has the potential to help reducing greenhouse gas emissions because it does not require the use of pumps or motors that give off greenhouse gases and plants used in phytoremediation may serve as sinks for the greenhouse gas CO_2 (Tsao,1999). Phytoremediation help eliminate secondary air or water – borne diseases where some plants accumulate PAHs from the atmosphere (Simonich et al,1994). It also indirectly, stabilizes the soil thus preventing erosion and human exposure by preventing the inhalation of soil particles carried out in the wind (Schnoor, 1995).

Ecological benefits served for new human settlements inside oil fields in Palogue. Resettlement of the nomad population is directly correlated with peace agreement and figures for southerners' returnees display an increase. The oil fields support these people by providing jobs in oil related activities, fishing, water for irrigated agriculture and alternatives for wood fuel, schools, dispensaries and other amenities. In April 2009 local people constituted 60.46% of patients being admitted to the health unit or got vaccination against children infectious diseases. Yet, peace agreement allowed for claiming rights on land owned by local people. Here, oil companies have established specialized legal authority for compensations that, if properly utilized, can work for local community development.

Infrastructure for oil exploitation included road construction, an airport, water stations, and new buildings, flourishing of local markets, passing of the highway Khartoum – Malakal via Palogue, introduction of education and health services among the population. All these have imperative implications for human capacity development. The distribution of such services can help for an even distribution of the population in accordance with economic activities. The benefits of oil exploitation into socio-economic development are well known by the experience of the Arab Gulf States. Traditional societies there passed over ignorance and poverty to new havens of modern life style. Oil transferred these societies to stages of safe technology oriented towards better use of natural resources.

Discussion:

Bioremediation provides a technique for cleaning up pollution by enhancing the same biodegradation processes that occur in nature (US EPA, 2006). Depending on the site and its contaminants, bioremediation may be safer and less expensive than alternative solutions such as incineration or land filling of the contaminated materials. Biological remediation significantly cuts costs and time generally associated with contaminant clean-ups and might involve introduction of new organisms to a site, or adjustment of environmental conditions to enhance degradation rates of indigenous fauna (Wikipedia, 2010). It also has the advantage of treating the contamination in place so that large quantities of soil, sediment or water do not have to be dug up or pumped out of the ground for treatment (Wikipedia, 2010). Due to such advantages and its wide worldwide application, Sudan can benefit from that and from Palogue's experience. Exploration of some world experiences and applications will further support that argument.

Palogue's experience on bioremediation can enhance sustainable development in Sudan by cleaning up the environment from oil pollution. Oil bioremediated water in Palogue has proved beneficial for the environment of the region where water lagoons were created for bird communities, domestic animals, some other wild animals, fishing and possibilities for agriculture, irrigation, animal watering and forest plantation. Future oil projects in Sudan have planned to hold oil water treatment without chemicals additives or the expensive electronic techniques by bioremediation techniques instead.

Worldwide, bioremediation provides a good cleanup strategy for some types of pollutants, but it will not work for all, such as high concentrations of chemicals including cadmium or lead, and salts such as sodium chloride that are toxic to most microorganisms. Bioremediation processes are used in applications such as groundwater remediation and soil remediation (US EPA, 2006, Perfumo et al., 2007). Bioremediation has potential to provide a low cost, non-intrusive, natural method to render toxic substances in soil less harmful or harmless over time (US DOE, 2006). However, bioremediation is also used for reduction of heavy metal in soils (Guo et al., 2010) and the recovery and cleaning up of a contaminated medium including soil, sediment, air, and water. The microbes break down the hydrocarbons and convert them to water, carbon dioxide and amino acids, which are natural and harmless.

Sediments dewatering is frequently necessary after dredging to remediate and treat contaminants. Methods for that include draining of the water in lagoons with or without coagulants and flocculants, or using presses or centrifuges. Treatment methods are similar to those used for soil and include pretreatment, physical separation, thermal processes, biological decontamination, stabilization/solidification and washing. Pretreatment may be one of the methods that can reduce costs by reducing the volumes of sediments that need to be treated (Catherine et al., 2001). According to Rajendran (2003) that microbial metal bioremediation is an efficient strategy due to its low cost, high efficiency and ecofriendly nature. Researchers in China have discovered that chicken manure can be used to biodegrade crude oil in contaminated soil (ScienceDaily, 2009). Further analysis of specific organisms present in contaminated beaches revealed the presence of several populations able to degrade polycyclic aromatic compounds such as phenanthrene or naphthalene, especially in those sites that had recently been restored after an important contamination episode. Probably due to the contamination record of the past in the Shoreline of Delaware Bay, indigenous populations had evolved to select for organisms able to grow and degrade components of crude oil (Albert et al., 1996).

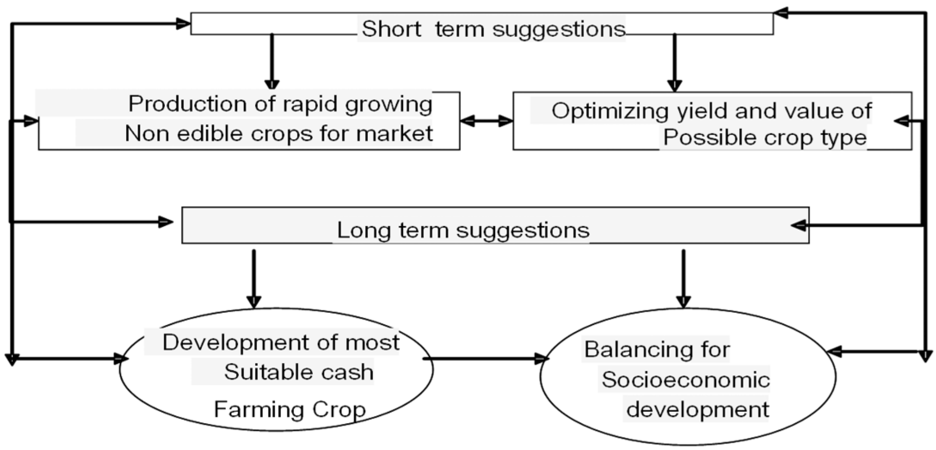
Bioremediation of soils, water and marine environments has many advantages. Due to the growing current trend around the world of drinking water from underground sources, in an attempt to replace heavily polluted surface water supplies, arsenic is causing a global epidemic of poisoning with hundreds of millions of people now being thought at serious risk in many countries. Phytoremediation has been proposed as an effective tool in arsenic cleanup where, some plants have been reported to be suitable for arsenic phytoremediation (Alkorta,2004). Fe (III)-reducing microorganisms can play an important role in the bioremediation of subsurface environments contaminated with organic or metal contaminants (Lovely, 2004). In addition to the bacterial biomineralization of organic pollutants, certain bacteria are also capable of immobilizing toxic heavy metals in contaminated aquifers, further illustrating the potential of microorganisms for the removal of pollutants (Parales, 2004).

In rural Australia, Organophosphate pesticide remains a major environmental contaminant and poses a significant threat to environmental and public health. Rapid biodegradation to support microbial growth has been suggested (Diaz, 2004) and the results have implications for the development of a bioremediation strategy (Foster, 2004). Pulp and paper mill effluents pollute water, air and soil, causing a major threat to the environment. The biological color removal process uses several classes of microorganisms--bacteria, algae and fungi to degrade the polymeric lignin derived, and chromophoric material (Murugesan, 2003). Studies have demonstrated that metal-reducing microorganisms can effectively promote the precipitation and removal of uranium from contaminated groundwater (North, 2004). The performance of microscale toxicity bioassays conducted on whole sediments was evaluated during bioremediation on a crude oil-contaminated freshwater shoreline of the St Lawrence River, that remediation treatment was able to accelerate detoxification (Blaise, 2004). Increasing number of microorganisms are being described for their ability to decolorize and degrade artificial dyes and novel bioremediation approaches for treatment dye bearing wastewaters are being worked out. These results indicate the potential use of C. gallica in bioremediation of tannin-containing industrial wastewaters and in other applications where a reduction in polyphenols content is required (Yague, 2000). All these experiences provide suitable grounds for Sudan to use and develop.

Conclusion:

Investigation into how to use oil water for environment and community benefits deserves priority from the viewpoint of planning policy and execution. Sudan is progressively entering oil era and by that way the future holds using of bioremediated oil water. A suggestion for future use of such a source is proposed for Palogue (figure 5) and is applicable for Sudan. The model is built on two terms. The short term targeting to produce rapid growing non-edible oil crop for market during toxicological test period, studying into optimizing yield and value of possible crop type. On the other side, the long term included the development of most suitable cash farming crop to balance for socio- economic development.

Figure (5)Suggestions for future use of biologically treated oil water in Palouge oil fields of upper Nile, southern Sudan



Progression in economic related activities could be strengthened through partnerships including caritas, District Fisheries, traders, micro credit finance, District Agricultural Office and banks. Yet, the most important ingredients of successful partnerships are trust, perceptions, and misconceptions. Nonetheless, challenges to rural poor involvement & participation in natural resources management, if any, could be identified and engagement strategy could be developed and presented with objectives to promote economic activities in a gender responsive manner so as to build peoples' capacity for production and manage ponds. Results have significant implications for decision making and site management.

Environmental planning could be part for future development and investment for conserving natural fauna and flora in oil producing areas in Sudan. However, environmental awareness is integral part for environmental planning. These rural communities should be aware with risks of climate variability and droughts and their result in a decrease in water availability and an increase in competition, and that high rates of population growth and subsequent increased demand have increased the pressure on the resources. They also should be aware that the possibility of increasing water scarcity may lead to water-related conflicts and political instability and should learn that sustainable use and development of water resources is a daunting challenge for both

the global and local communities and It requires commitments by all groups within all levels, and that without a set of coherent legal arrangements designed to ensure effective governance of water resources, their sustainable use and development are unlikely to be achieved. UNESCO (2010) proposed Integrated Water Resources Management (IWRM) as a tool for adaptation to climate change that will lead to an intensification of the global hydrological cycle and will have a major impact on regional water resources. It is also clear that, in many parts of the world, variability in climate conditions, next to many socio-economic and environmental developments, is already having major impacts and that such variability is increasing. Still yet, a national strategy is needed to support further adaptive methods, such as that of Palogue, for environment conservation in Sudan.

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2

Ecological Impacts of Mesquite "Prosopis spp." Expansion in Toker Delta, Northeastern Sudan

2

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Mesquite which means "towards abundance" is widely spreading in different habitats. There are three common species of mesquite including Honey Mesquite (Prosopis glandulosa), Screwbean Mesquite (Prosopis pubescens) and Velvet Mesquite (Prosopis velutina). They are thorny leguminous shrubs or trees belong to the leguminosae family. It ranges from 1.0-meter tall shrubs to 18.0-meters tall trees with roots grow deeply downwards in search for water up to 50.0-meters (Asim, 2007). Mesquite was spread via ruminants which ingest seeds and excrete them in manure which is a common source of fertilizer for agriculture. With a high content of hard seed, passage through the digestive system of ruminants acts to scarify mesquite seed.

The mesquite species is a weed of world significance due to its invasiveness and subsequent ecological, economic and social impacts (Robinson, 2008). It is invading India, Pakistan, South Africa, Egypt, Kuwait, Australia, U.S.A. (Hawaii), and Brazil, (Kay, et al., 2007), southern Arizona (Arizona Board of Regents. 2009), Western Australia (Robinson, 2008), semi-arid regions of northern Mexico and the southwestern USA (Brunel,2009), upper San Pedro River watershed, which extends from northern Sonora (Mexico) to southeastern Arizona (Brunel,2009), covers almost one million hectares of Australian land with the potential to cover 70% of mainland Australia (EKSA,2010), the Rusizi floodplain and delta (IUCN.2010), Baringo District of the Rift Valley, Kenya (Okello,2008). In Kassala State, eastern Sudan, mesquite invaded valuable agricultural lands and sometimes grows into impenetrable thickets causing enormous problems to farmers and agricultural managers (Abdelmagid, 2008). Similarly, in New Wadi Halfa scheme in eastern Sudan, mesquite spread had created on-farm problems in spite of the various benefits provided (Mai, 2008).

Although of these threatens , mesquite as leguminous plant increase soil fertility, need irrigation once or twice when firstly planted, grow rapidly, do not invade rainfed irrigated areas with heavy dry clayey soil and also incapable to spread into sandy soil areas. Mesquite have delicious fruits attracting animals and children, have grazing and nutritional values for its sugar content, protein and salt minerals. In Mexico, mesquite is the main source for feeding livestock and wild animals. In Yemen, every km of mesquite belt gives 10 to 25 cubic meters of wood income per year and provides fodder for fifty head of sheep and goats (Bazraa, 1983).

Socio-economic and ecological impact of mesquite has been controversial during last years. The main objectives of this paper are to investigate ecological impacts of the spatial expansion of mesquite “Prosopis spp.” in Toker Delat scheme and to propose some suggestions to alleviate its negative impacts

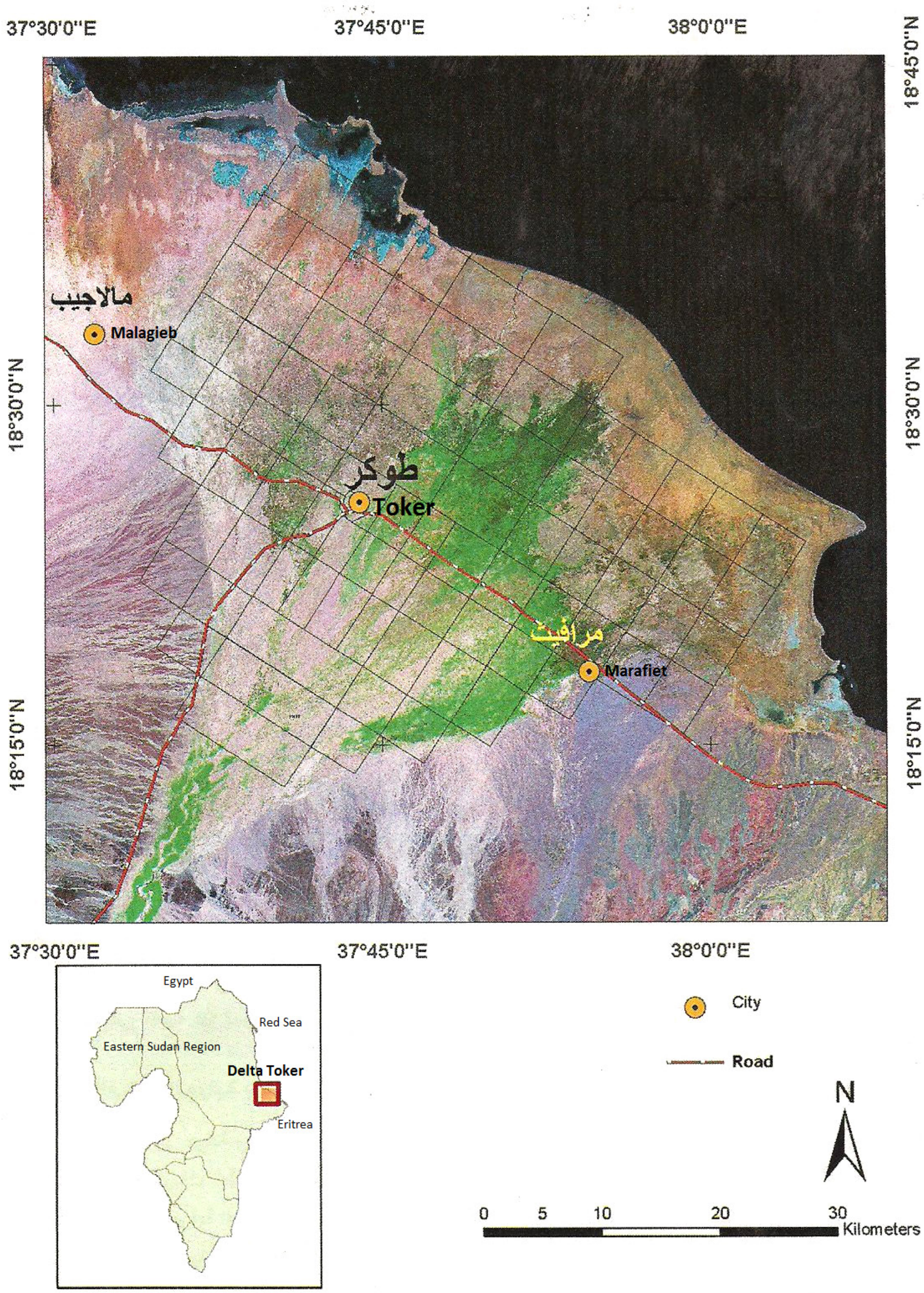
The study area:

Toker Delat locates between 18^0 $18^/$ - 18^0 $40^/$ N and 37^0 $30^/$ - 37^0 $55^/$ E, and administratively belongs to the Red Sea state which is one of the eastern Sudan region’s states (Fig.1). Toker Delat locates close to the main sea ports of Trinkitat by 22 km, Suakin by 90 km and Port Sudan by 160 km (Wikipedia, 2011). The scheme was founded by the Turkish Governor Mumtaz Basha, 1871-1872, who was the first to introduce cotton in Sudan. The scheme was halted during Mahadist rule, 1885 – 1898, and by 1900 the British cultivated 200 feddans by cotton (ACSAD, 2005). Toker – Trinkitat light rail way was built in 1921-22 to transport cotton to the coast for export (Daly, 2002). In 1952 Toker Delat was very famous by organic cotton production when the major client was the British Lancashire Textile Factories.

Barak River flows seasonally with over 640 km length and 55 km width (Wikipedia, 2011). It originates in Ethiopia at 15^0 N and bifurcates in Eritrea into Baraka and Ansaba. When enters Sudan, it joins with Khor Langaib and the channel becomes wider with slope of 1.5:1000. In south east Toker by 33 km, it enters a narrow gorge and passes through Shiddin cataract where its slope reduces to 1:1000. When it enters the coastal plain, it bifurcates into three branches watering east, central and western parts of Toker Delat. This Delta has an equal axis triangle shape; the base line is parallel to the Red Sea coast while the other two axes are 45 km length (Fig.1). It has an area of 1624 km^2 and average slope of 86 cm/km (ACSAD, 2005).

In Toker Delat, about 70% of the rain falls down during November to January. Average humidity is 59%, temperature range is 22 – 46 C^0 while average sunshine range is 6 to 8 hours a day. ''Haboob'' winds blowing from October to December kill insects and vectors to allow for no use of pesticides which is advantageous for organic food. The hot ''Ahataib'' winds, blowing from June to the beginning of August, invert soil and reduce soil tillage cost. Wintry rains help complementary irrigation. Torrential floods bring high sediment load which increase soil fertility. In 1973, the loamy soil of Toker Delat rated higher relative to Pennsylvanian soil which was the most fertile soil in the world. Baraka River comes splashing with high suspended sediment load ranging from 250 to 980 Million M^3 of silt (Office Files, Scheme Headquarters 2011). It carries 10.6% of its water as suspended sediment load. This amount of silt equals fourfold the annually deposited amount of silt brought by the River Nile and exceeds Gash's River, which is another torrential river in eastern Sudan by 1: 10^5 (Alredaisy, 2011). These huge amounts of silt accumulate in different areas of the Delta according to flood discharge. They are deposited into new strata added to the soil, differing in thickness by place and time of the year. It is annually flooded and more than 406,000 feddans (1 feddan = 4200 m^2) are inundated by flood water. Flood starts in mid July up to September in duration of 40 to 70 days. It is violent and strong with flood interval ranging from few hours to several days. Water discharge might reach 1200 m^2/s. The annual average discharge of Baraka River is 400 million m^3 and annual amount of water ranges between 205 and 980 million m^3 (ACSAD,2005). The highest estimated discharge is 800 million m^3, the moderate is 500 million M^3 and the lowest is 200 million M^3 of water. The coefficient of surface runoff is 0.012 (ACSAD, 2005). Nearly 60% of this amount of water is discharged into the Red Sea (ACSAD, 2005).

Location of the study area in eastern Sudan



Source: ACSAD (2005)

The aquifer of the Delta is composed of alluvial sediments including a zone composed of dry sediments of silt and sand, underlain by a zone of freshwater aquifer with a thickness of 10 to 80 m and a surface area of 200 km^2 (El Gaily, 2007). This is underlain by a transition zone of brackish water bearing layers and a thickness of a few meters to tens of meters. This zone is underlain by a zone reflecting saline water-bearing formations or possibly clayey layers with an average thickness of 15 m. The annual groundwater discharge is 32 million m^3 (El Gaily, 2007). It is recharged annually by 31 million m^3 from the flood water of River Baraka. Groundwater in storage is estimated as 600 million m^3. The average yield of the boreholes is estimated to be 40 m^3/h, but the dug well yield is low (5 to 10 m^3/h) (El Gaily, 2007). Depth of artesian wells ranges between 10 and 20 meters with average pumping of 15-25m^3/hour (Toker Delat Agricultural Scheme, Irrigation Section Files, 2011). Irrigated area during high discharge reaches 50,578 feddan while in low discharge it reaches 10,115 feddans.

Fig.2. Mesquite in Toker Delat

Mesquite was firstly introduced in the scheme in 1962 by Forestry Authority to stop wind erosion that particularly caused by ''Ahataib'' winds and to stabilize sand dunes and to reduce dust. Its growth was promising to encourage further plantation for sand dunes stabilization. In addition to those benefits, mesquite became a source of income for charcoal traders and food source for animals. Mesquite is found to be spreading through camels and goats excreta. The two types of Schlensh and P. juliflora mesquite dominate the Delta (Abdulmagid, 2008). They are highly resistant to harsh environmental conditions, denser and reproductive twice a year and highly competent with natural fauna. Their height range between 4 to 7 meters and stem thickness ranges 12 to 20 cm with 600 trees per feddan (Asim, 2007). By 2011 mesquite occupied 76% of the total area of the eastern Delta and 48% of the central Delta area.

Methods:

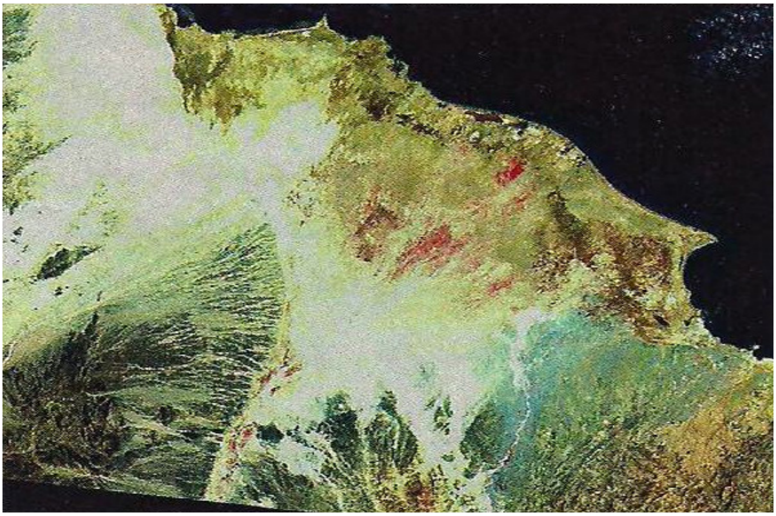
The field work was carried out through general discussions (research type interviewing methodology) with farmers and Head of staff of the scheme during 27-30 March 2011. The Delta is divided into three sections, eastern, central and western. In each section, two groups of farmers including 10 to 14 persons were interviewed. They were collected by Heads of farmers whom were firstly contacted to facilitate group discussion. Farmers are chosen according to their accessibility during time of interviewing. General collective discussion with these groups of farmers was focused on problems of mesquite expansion and the associated ecological impacts. Head of farmers have substantially contributed into the administration of discussion into making language of communication between interviewer and interviewee more accessible and easy to understand. In addition, office data is used.

Satellite images have been used to show areal expansion of mesquite in the delta. They have included Landsat MSS for 1976, Landsat TM for 1986 and Landsat ETM for 2000 which were provided by ACSAD (2005). The progress of mesquite into the Delta was detected in the years 1976, 1986 and 2000. This helps to show spatial expansion of mesquite since a span time of ten years between 1976 and 1986 and fourteen years between 1986 and 2000. Satellite image of 1976 shows mesquite appears in red color, while in the satellite images of 1986 and 2000 it appears into green.

Based on ArcGis 10 and ERDAS Imagine 8.5, the analysis of these satellite images is done. Each image was divided into classes including mesquite class which is gives OID and value 7 in each image. In figure 7, the Red Sea is given red color while in figures 6 and 8 it appears in black color. In all of the images analysed, ther vegetation types have given OID and values according to density. In figure 7, light purple and blue tending towards white indicate to deposition by Baraka River. Opacity means degree of darkness in each color found in the image.

Annual rate of mesquite expansion in the Delta is estimated by dividing the total area occupied by the number of years since introduction of mesquite into the scheme in 1962. This gives 49 years time span between 1962 and 2011.

Fig. 3: Toker Delat1976, beginning of mesquite expansion in red color Landsat MSS.

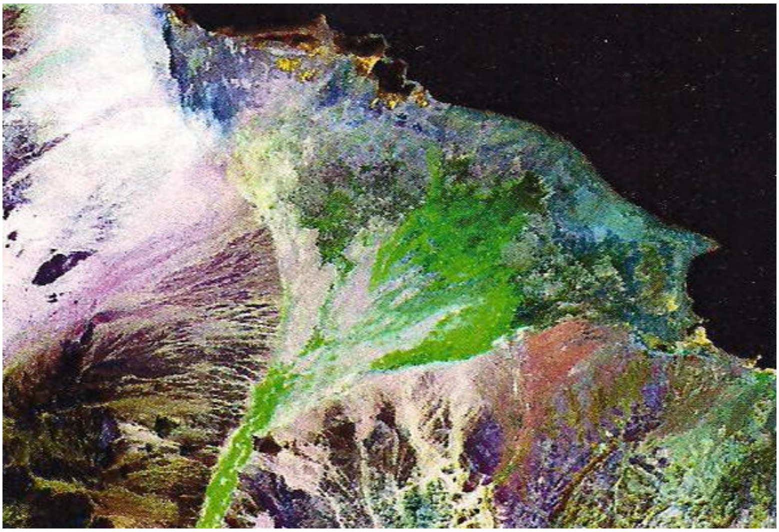


Source: (ACSAD, 2005)

Fig. 4: Toker Delat in 1986, expansion of mesquite in green color. Landsat TM.

Source: (ACSAD, 2005)

Fig. 5: Toker Delat in 2000, occupation by mesquite in green color. Landsat ETM.



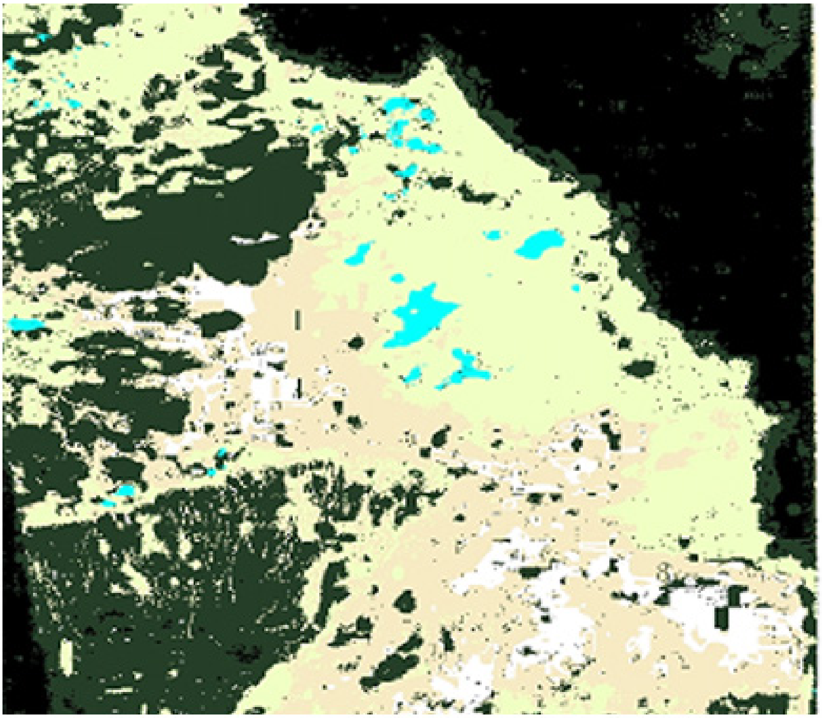
Source: (ACSAD, 2005)

The main studies and projects that provided most of the information within this manuscript have included Asim's study (2007) on mesquite impact in Toker Delat has provided information on the nature of this tree and its impacts. Elgaily (2007) has studied the aquifer characteristics of Toker Delat and provided basic information about that for the study here. The Kuwait fund for eastern Sudan in collaboration with the Government of Sudan and international donors and investors conference for development of east Sudan, Kuwait 1-2 Dec. 2010, have also provided good information about potentials, mesquite and high siltation problems in the study area (www. kuwaitfund.org/eastsudanconference. Sudan productive capacity recovery program (SPCRP2010) has studied Toker Delta agricultural scheme and made available good information on mesquite problem and methods of combating its future expansion. The study by Engineer Osman (2010) on the negative impacts of mesquite trees in Toker Delat was also very benefit to discuss the human side into this problem (Osman, 2010). The study on production of vegetable for export in Toker Delat has highlighted the problems of agricultural production as due to mesquite expansion (Sudan economy.com.2010). Rehabilitation of Toker Delat sponsored by Government of Sudan has also highlighted the scheme's problems and strategies for how to overcome them (Sudantribune.com.2010).

Mesquite expansion in Toker Delta:

Satellite image showing mesquite expansion in Toker Delat in 1976 (Fig.6), depicts that mesquite was restricted to few parts of the Delta. It is noticed that mesquite (in green color) is dispersed in the central parts of the Delta; occupying small pockets along the main channel and has discrete distribution.

Fig. 6: Toker Delat1976

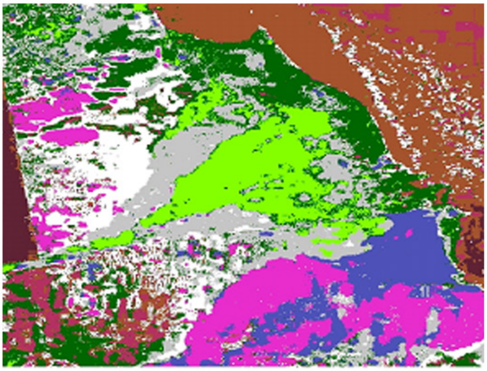


OID	Value	Count	Red	Green	Blue	Opacity	Class_Names
0	0	0	0	0	0	0	Unclassified
1	1	0	0	0	0	0	
2	2	0	0	0	0	0	
3	3	0	0	0	0	0	
4	4	0	0	0	0	0	
5	5	37125	0.1547	0.3135	0.8452	1	Class 5
6	6	52104	0.1207	0.0592	0.0879	1	Class 6
7	7	45355	0.6274	0.1254	0.9411	1	Class 7
8	8	19039	0.6278	0.2351	0.1721	1	Class 8
9	9	23317	1	1	1	1	Class 9
10	10	0	0	0	0	0	
11	11	0	0	0	0	0	
12	12	48168	0.3294	0.8410	0.1589	1	green land

By 1986, it occupied further areas (Fig.7), forming continuous expansion taking the triangle form of the Delta. During a decade, 1976 to 1986, mesquite increased by a rate twice the rate for 1962 – 1976 which spans for 15 years.

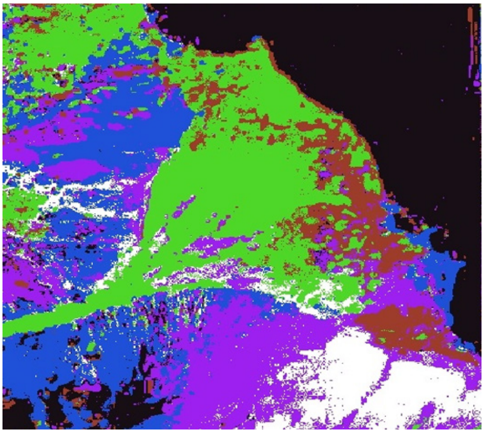
By the year 2000, mesquite completely occupied the main channel of Baraka River entering the Delta and the majority of Delta's central area (Fig.8).

Fig.7: Toker Delat in 1986



OID	Value	Count	Red	Green	Blue	Opacity	Class_Names
0	0	0	0	0	0	0	Unclassified
1	1	0	0	0	0	0	
2	2	0	0	0	0	0	
3	3	0	0	0	0	0	
4	4	48722	0.5059	0.9740	0.7926	1	Class 4
5	5	0	0	0	0	0	
6	6	39133	0	0	0	1	Class 6
7	7	2490	0.2744	0.2533	0.8066	1	mesqeete
8	8	11458	1	1	1	1	Class 7
9	9	0	0	0	0	0	
10	10	57444	0.2509	0.8784	0.8156	1	Class 9
11	11	64847	0.1409	0.2390	0.1504	1	Class 10

Fig. 8. Toker Delat in 2000



OID	Value	Count	Red	Green	Blue	Opacity	Class_Names
0	0	0	0	0	0	0	Unclassified
1	1	0	0	0	0	0	
2	2	32895	1	1	1	1	Class 2
3	3	0	0	0	0	0	
4	4	10633	0.6901	0.1882	0.3764	1	Class 4
5	5	33988	0.7529	0.7529	0.7529	1	Class 5
6	6	39274	0.6274	0.3215	0.1764	1	Class 6
7	7	19738	0.4980	1	0	1	Class 7
8	8	25396	0.8853	0.1746	0.7784	1	Class 8
9	9	38992	0	0.3921	0	1	Class 9
10	10	16595	0.2999	0.3111	0.7000	1	Class 10
11	11	0	0	0	0	0	
12	12	0	0	0	0	0	
13	13	7597	0.3642	0.1357	0.2047	1	Class 13

In 1986 mesquite covered an area that equal double the area used to occupy in 1976. I t has expanded spatially by 100% and between 1986 and 2000 by 75%. This can be viewed as very quick rate of expansion. By 2011 mesquite occupied 76% of the total area of the eastern Delta (95,000 feddans out 125,000 feddans), 48% of the central Delta area (80,000 feddans out of 167000 feddans). The western delta has been abandoned because it was occupied by Adlib trees and sand dunes. Progression through time, mesquite has occupied 73% of the total area of Toker Delat (300,000 feddans). The annual areal expansion of mesquite in the Delta between 1962 and 2011 is estimated at 6,122 feddans per year.

Mesquite was found to be well adapted to places with high moisture content including drainage lines, irrigation canals, bridge inlets and outlets and irrigated farm lands, bare land unexploited by agricultural or forestry activities and neglected lands having reliable humidity for growth. It has been less successful on land where native vegetation is still vigorous, light soil susceptible to water and wind erosion (Fig. 9)

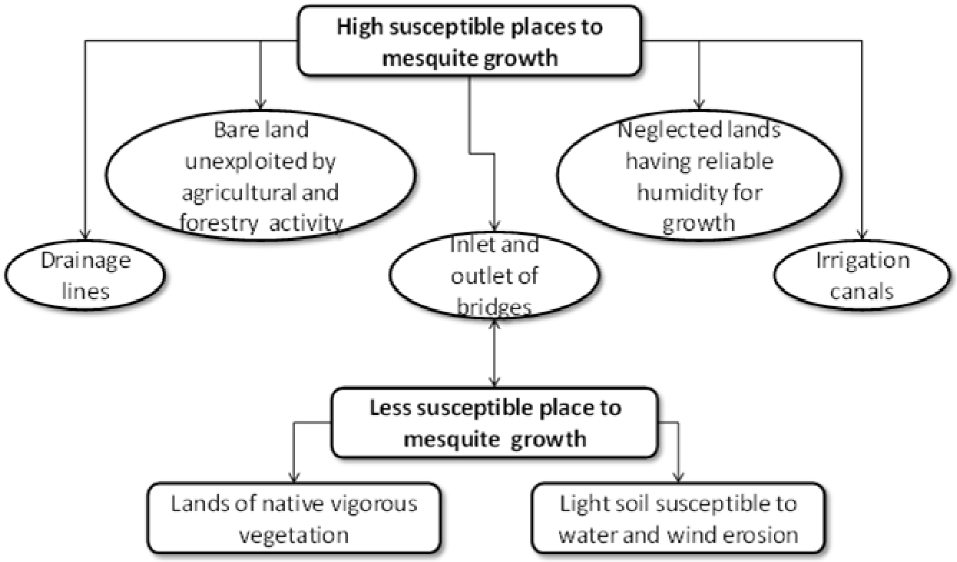


Fig. 9.Classification of place of mesquite growth by degree of susceptibility

Ecological Impacts of mesquite expansion:

Mesquite's ecological impacts in Toker Delat could be discussed from sides of water depletion, obstruction of renewal of natural fauna, declining of cultivable and cropped area and causing conflict among natural resources beneficiaries in the Delta.

Mesquite depletion of surface water is evident by surface inundation of the Delta during flood season where mesquite areas have changed into dense forests (Figs. 6, 7, 8). Since mesquites occupy 300,000 feddans out of 406,000 feddans, this means that 73% of water inundating the Delta is consumed by mesquites. The annual average discharge of Baraka River is 400 million cubic meters and nearly 50% of this amount of water is discharged into the Red Sea while 31 million cubic meters recharges the aquifer. Therefore, out of the remaining 170 million cubic meters left as surface water, excluding evaporation, mesquite consumes around 127 (73%) million cubic meters of the available surface water. Since the estimated number of mesquite trees per feddan is 600 and occupy 300,000 feddans, we can induce that there are 180,000,000 mesquite trees covering the Delta. The amount of surface water consumed annually per a mesquite tree could be estimated as 0.70 cubic meter of water.

Mesquite depletion of the Delta's aquifer water is confirmed by referring to Gaily's study (2007). That study has revealed a zone of freshwater aquifer that has a thickness of 10 to 80 m and since mesquite roots are capable to penetrate down to 50 meters, it will find this rich bond of freshwater. Mesquite work as pumps drawing fresh water, in addition to huge amount of fresh water mixed with sea water, affecting availability of suitable water for cropping.

Mesquite influence on renewal of natural fauna is that most notably, mesquites' root systems give the plants a competitive botanical edge in such landscape of Toker Delat. As hosts to nitrogen-fixing bacteria, they help enrich otherwise impoverished these soils in which the plants and their progeny grow. Mesquite competes with other plants in the battle for soil moisture. In their tap roots' downward reach, they find subsurface water. The mass of surface roots usually results in the complete loss of grass cover. Very high pod production occurs as 3.34 kg per tree ensuring rapid spread, with seedlings germinating at very high densities forming thickets. Seeds can be transported long distances by camels, goats and sheep which are estimated as 600,000 head in the scheme, and by water to favorable sites some distance away. It competes with palm trees which eastern Sudan is famous by and eventually killing them. The allelopathic effects from ground litter of mesquite pods and leaves usually extracts, prevents the seeds of other species germinating. Dense infestations would reduce habitat of native fauna, reduces carrying capacity, longevity of the seed and dense infestation likely to have a major impact on land value.

Because mesquite is aggressive invader and competitor and because of its thicket-forming characteristics, it reduces available grazing area and limit ingress to watering points. Only the pods are palatable to livestock and not the leaves. This means that large quantities of pods are consumed and excreted in manure.

Mesquite has declined annually cropped area and crop productivity in the Delta through changes that could be detected from 1900 through to 2011. Between1900-1926, cultivated area did not exceed 50,000 feddans in most years, except some years when cultivated area exceeded 120,000 feddans with 45,000 feddans as general mean of cropped area. Between 1927 and 1976, cropped area increased to 77,000 feddans and even exceeded 150,000 feddans for four times and 100,000 feddans for eleven times. Following that period, mesquite spread in areas of water and fine sediment accumulation behind the established barriers. Cropped area greatly declined to 62,000 feddans.

Fig.9. Mean annually cropped area, 1997-2011

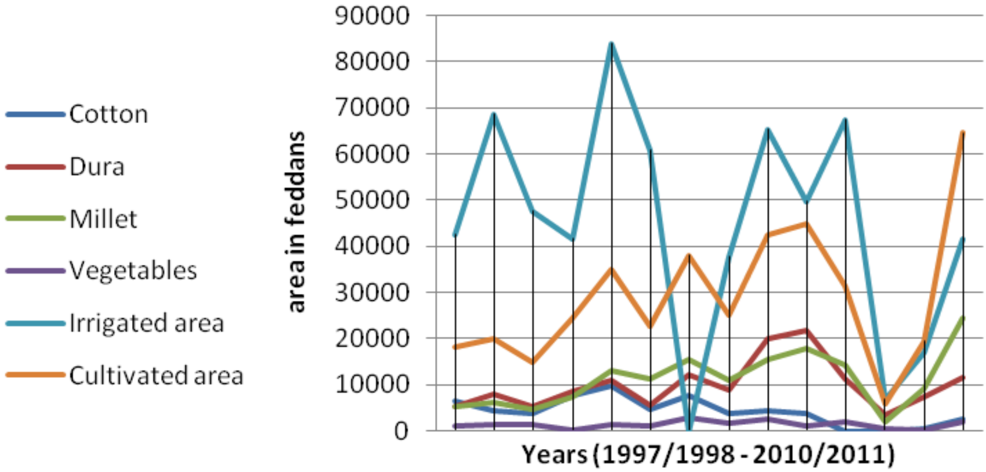


Figure (9) shows annually cropped area between 1997 and 2011. Vegetables area curve is almost smooth. Cotton area is declining. Dura area is fluctuating, increasing for most of the period then sharply declined but returned to go up increasing. Millet area is fluctuating. Cultivated area by a crop type shows sharp ups and downs trends as well as having small size allocated area.

Other expected ecological impacts of mesquite occupation of Toker Delat might include increase of photosynthesis process, blocking flow of water along water ways resulting in flooding, can protect valley banks against erosion accumulation of blown sands around the mesquite bushes, hosting pets and works as trap for plastic bags easily brought by winds which are later dumped into the soil of the Delta. This is noticed in the southern part of the Delta close to Toker town. Mesquite might have reduced wind velocity, water loss due to evaporation, improving soil texture and clayey soil content, ratio of organic matter and total increase in Nitrogen. This might be confirmed by the study in Tendelti area in western Sudan which is considered environmentally similar to Toker Delat where mesquite had reduced wind velocity by 14.4% and water loss due to evaporation by 22%, improving soli texture by 5% of clayey soil contents by 7% and ratio of soil organic matter to 3500 kg and total increase in Nitrogen by 11% (El Fadl, 1997). Also, it might have improved agricultural environment as in Karma and Zaidab basins in northern Sudan (Abdelmagid, 2000).

Mesquite has created ecology of conflict between its beneficiaries including farmers, herders and charcoal traders. Farmers look at mesquite as invading and colonizing their land while herders and grazers perceive it as source of fodder for their animals and provide shadow during dry hot season and furthermore can be used as a live hedge to control stock movements. Charcoal traders consider mesquite as source for money income and supplies fuel for rural poor due to its excellent charcoal.

Discussion:

Mesquite species have been widely introduced to native arid and semi-arid regions of western Asia, Africa and the Americas to combat desertification and sand encroachment due to their ability to survive in inhospitable locations and provide a source of fuel, timber, fodder and edible seedpods. In Toker Delat, mesquite invasive nature has created many ecological impacts similar to many habitats worldwide. In El Getaina town and surrounding areas in central Sudan, mesquite is widely spreading along the White Nile banks (Yousif, 2005). In southern Arizona, velvet mesquite began to invade upland grassland environments and is generally associated with a combination of factors caused by very high livestock densities, severe drought, and reduced fire frequencies. It is generally assumed that this invasion is driven principally by ecological changes that permitted mesquite seedlings to establish and persist in upland environments (Arizona Board of Regents. 2009). In Western Australia, it was determined that the shift from grass to mesquite domination had been rapid, with rates of increase in canopy cover comparable to invasive populations where it is native. The rate of patch recruitment was high in all land types including stony flats, red-loamy soils and the riparian zone. Similar to Toker Delat, mesquite had been spread by sheep and macropods and the recent switch to cattle is likely to exacerbate spread as it is a far more effective dispersal vector; and early succession patterns (Robinson, 2008).

The ecological impact of mesquite into competing with natural fauna in Toker Delat is also similar to many semi arid regions in the world. Vegetation structure in semi-arid regions of northern Mexico and the southwestern USA has changed dramatically over the last century where mesquite shrubs have expanded into, and have become dominant in, ecosystems that once supported semi-arid grassland (Brunel, 2009). Prosopis cineraria and P. juliflora were introduced to the Wadi Hadramout in Yemen in the mid-sixties and in 30 years, P. juliflora (mesquite) has spread from just a few trees and now occurs extensively throughout the 2.25 M ha Wadi (Elsiddig, no date).

However, depletion of surface and aquifer water has led to loss of flood water for irrigation and agricultural expansion to commensurate with increasing population and reduced the annually cropped area. The associated results were Lack of job opportunities; outside migration to Port Sudan town and other urban centers in Sudan, spread of poverty due to weak income generating activities particularly among women and problems of food insecurity and malnutrition and increasing production cost similar to situation in Western Australia where mesquite infestations have increase harvest costs and hindered mustering" (Victoria Resource on Line, 2011).

Conflict among beneficiaries of mesquite and farmers in Toker Delat is similar is to the situation among tens of thousands of Burundian and Congolese where mesquite supports their livelihoods although they cultivate, fish, graze cattle and harvest wetland products (IUCN.2010). This is similar to Rusizi floodplain and delta where invasive species also threaten the ecosystem and the livelihoods dependent upon it (IUCN.2010). in El Getaina town and surrounding area in central Sudan, mesquite is creating several problems to local people by causing hindering the freedom of movements where 71% of respondents agree with the spine of mesquite is harmful and blocking the entry to the Nile banks (Yousif, 2005).

Influence of mesquite on grazing areas in Toker Delat is similar to the upper San Pedro River watershed, which extends from northern Sonora (Mexico) to southeastern Arizona (USA), which have witnessed changes in grazing areas. Between 1973 and 1992, grasslands decreased by 18% and the total area dominated by mesquite increased during the same period by 412%. In the areas where the density of mesquite shrub is medium to high, grass has completely disappeared under the shrub canopy and has been replaced by bare soil (Brunel, 2009). In Australia, mesquite now covers almost one million hectares of Australian grazing land with the potential to cover 70% of mainland Australia (EKSA, 2010). About 30,000 people are affected in Marigat Division in the Baringo District of the Rift Valley, Kenya where mesquite has been blamed for encroaching onto grazing land, blocking roads and watering points, drying up rivers and changing their courses (Okello, 2008). However, Euler et al., (2010) noticed an increase in organic matter content with values ranged from 0,86% to 2,19%, in sols cultivated with Prosopis in Northeast region in Brazil which accords with other studies that in soil with prosopis crop there is an increase in the levels of organic matter, it is probably because of the leaves and branches that fall which protect the soil. Moreover, mesquite as a tree provides fuel wood energy and is used as fire wood, for construction where the study in Geteaina area in central Sudan had shown that 77% of the population surveyed agreed with the main dominant and available range plant is mesquite (Yousif, 2005).

Conflict among beneficiaries of mesquite is reflection of conflict on meager resources and is essential into future management of natural resources. Meager resources usually cause ecology of political conflict where tension has risen in eastern Sudan by the two rebel groups of Beja Congress and the Free Lions Movement who share many of the same grievances of Darfur rebels, accusing Khartoum of neglecting the impoverished area.

Conclusion:

The main findings of this study are:

1- Areal expansion of mesquite in the Delta between 1962 and 2011 was estimated at 6,122 feddans per year.

2- Mesquites has depleted surface and underground water, obstructed renewal of natural fauna and declined cropped and grazing areas

3- Mesquite has some benefits to the environment.

Because mesquite has caused many negative impacts in the environment of Toker Delat, suggestions would work towards its eradication. Eradication should include preventing more expansion in the unaffected parts of the Delta, use of mesquite forests into charcoal and honey production and gradual replacement of mesquite by forest cultivation and reforming of land holding system. Mesquite can be eradicated through field studies focusing on topography to know about suitable locations for mesquite growth in order to prohibit future invasion. Direct investment into mesquite eradicated areas is essential in order to avoid mesquite re-invasion and water accumulation to avoid forests formation through building of fences and sanctuaries. Technical administration of mesquite forests has proved efficient which considers mesquite as a resource that has to be managed properly. The most important element in this type of management is to reduce mesquite density so as to achieve ecological and economic balance through manual cutting. National Forestry Authority and Center for Forestry Research have carried out many experiments to control mesquite expansion in Kassala province in eastern Sudan and Suba area in central Sudan through cutting. Cutting of mesquite stems at 25, 50 and 75 cm depth has profoundly affected eradication of mesquite if being burnt or not.

Training of farmers, herders and charcoal traders on efficient methods of mesquite cutting under supervision of technical staff is important. In addition, completion of forests resources survey, collection of relevant data on the climate, dust storms and soil have to be stored in database in order for establishing tree belts and forests' plants. Rehabilitation of vegetative cover should include efforts of enhancement of natural renewal of forests, organizing grazing and supplying herders and farmers with technical packages concerned with plantation of trees, seeding of seeds in valley and water accumulation areas, rehabilitation of Toker nursery and encouraging individually owned nurseries and training of charcoal producers on modern methods for charcoal production.

Making benefit from the experiences of northern and Nile states of the Sudan into mesquite eradication through Agricultural Extension was vital into mesquite eradication due to the awareness of farmers. Technical method preventing mesquite flowering such as that used also in preventing sugar cane flowering will help into mesquite eradication. Biological methods could include improvement of local trees, use of some insects that are feeding on mesquite fruits and blossoms such as Mozena obtasa and Cutworm have proved excellent USA feeding.

Because camels and goats are most effective into mesquite spread there should be an alternative for animal feeding through plantation of local trees in some valleys outside the scheme followed by prohibition of camel grazing inside the scheme. This could be enhanced by the fact that Toker Delat has marginal potential for rainfed agriculture. In southwestern United States, "Many species of mesquite respond positively to overgrazing and grasslands are subsequently converted to mesquite brush lands. Conversion back is very difficult and temporary with reduced grazing pressure." (Victoria Resource on Line, 2011). However, annual flooding provides a source for development of water managed farming system and creates a node for dry season grazing by livestock of pastoralists.

Due to conflict created by the presence of mesquite between farmers and other beneficiaries, policy makers have to consider that into eradication of mesquite.

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3

Climate change and Environmental Impacts in Sudan

3

Climate change and Environmental Impacts in Sudan

Most of Sudan's territory is located within the arid and semi-arid regions of tropical Africa, where the humid part lost most of its area after the secession of South Sudan in 2011 AD. These arid and semi-arid regions are characterized by climatic characteristics, the most important of which is the fluctuation and irregularity of rainfall amounts during the rainy season, with high average seasonal temperatures and annual evaporation rates. The global climate has witnessed clear climatic changes in recent decades as a result of many reasons related to industrial progress and population increase, which has had a negative impact on many parts of the world, including the areas in which Sudan is geographically located. There is much scientific evidence confirmingthe occurrence of climate change in Sudan and the consequent environmentalimpacts. This will be the concern of this researchbased on relevant scientific research.

Indicators of climate change in Sudan:

Tropical Africa, which includes Sudan, has witnessed climatic changes confirmed by radiocarbon dating and analysis of micro-fossil plants of tropical lake sediments.The early Holocene was wetter than it is today across the entire tropical region, in contrast to the last glacial maximum, which was cold, dry, and windy. Evidence has been found of wetter conditions on the Red Sea Hills at that time compared to today, and this also applies to most of North Africa (Mawson, et al., 1984). Records in eastern desert lakes show that early Holocene oscillations affected the water levels and salinity of the hydrological systems of these isolated lakes as much as they were isolated from larger groundwater systems (Hoelzmann et al. 2010). In the Mansurab Valley, which is 15 km west of the lower White Nile, and which lies within the dry range of present-day north-western Sudan, semi-aquatic shells have been found in the silt and clay of the shallow depression (Williams et al. 2011). This is linked to the early Holocene, which confirms that the climate was humid with a strong indication in this part of Sudan. This also matches shells found east of the lower White Nile. These results confirm that wetter regional conditions were associated with times of high Nile flow in the early Holocene (Williams et al. 2011).

Historical fluctuations in precipitation occurred over the Nile Basin, which was reflected in its drainage, as precipitation zones migrated latitudinally over the Middle Nile by about 600 km during the past 20,000 years. Decadal changes in precipitation occurred during the twentieth century and reached 20% of the changes that occurred in the Holocene. This reflects the sensitivity of the Nile Basin to many factors operating at different times as well as spatial dimensions that include changes in the Earth’s orbit, global ocean temperature anomalies, ITCZ migration, and land cover changes across the African continent (Hulme, 1994).

The swamps of South Sudan (Sudd) work to change the local energy budget by increasing the flow of latent surface heat. Their presence leads to a lower ground temperature (up to 2 degrees Celsius), a large thermal gradient extending from north to south, and an increase in the local rainfall rate(Up to 40%). Particularly important is its effect on rainfall in neighboring regions. Such effects were not found mostly on rainfall over the source region of the Nile in Ethiopia or in the Sahel region, but they are appropriate for the humid conditions over central

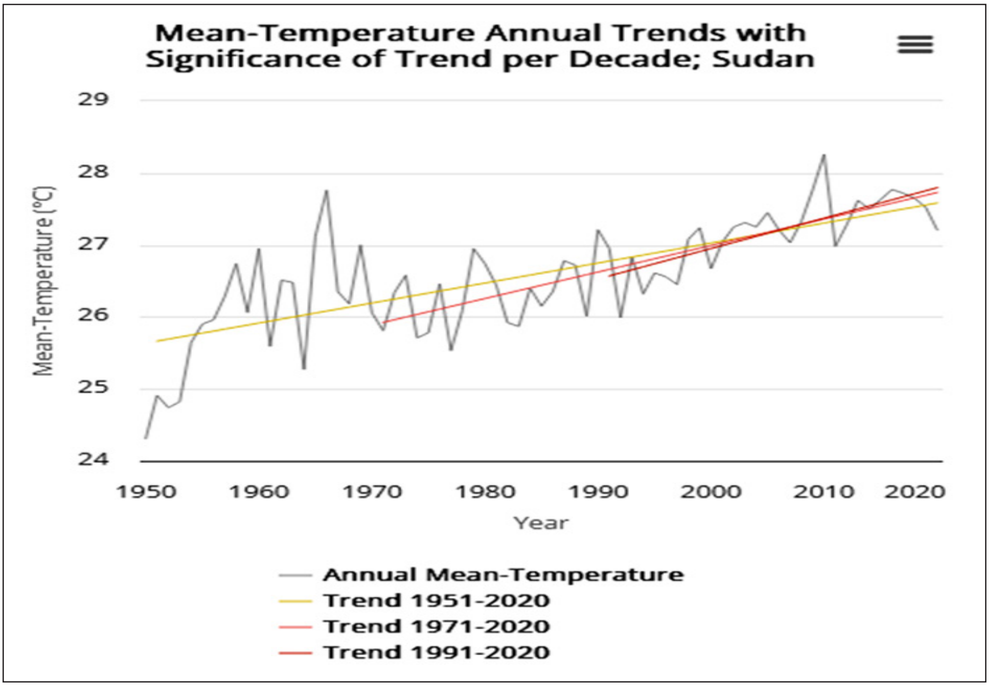
Sudan (up to 15%) compared to the conditions of bare desert soil(Modathir et al. 2013).

The Sudanese Sahel region is characterized by being an arid to semi-arid region. It relies on seasonal rains as the primary source of water, and its rains have interannual variability, as rain fluctuations are linked to the moisture transfer process. The main origins of most of the air masses that reach this region during the monsoon period are over the Arabian Peninsula and Central Africa (not the country), or they are linked to the eastern tropical jet. The flows associated with the movement of the ITCZ contribute half of the amount of water falling into it, most of which comes from Central Africa. This suggests that moisture recycling is the main contributor compared to oceanic sources. Flows from the northeast (the Arabian Peninsula and northern Asia) and the east (the Horn of Africa and the northern Indian Ocean) contribute about a third of the falling water. The remaining waterfall comes from the Mediterranean Sea and the West Coast with smaller contributions, and the different sub-regions of the Sudanese Sahel have different sources of moisture (Salih, et al. 2015).

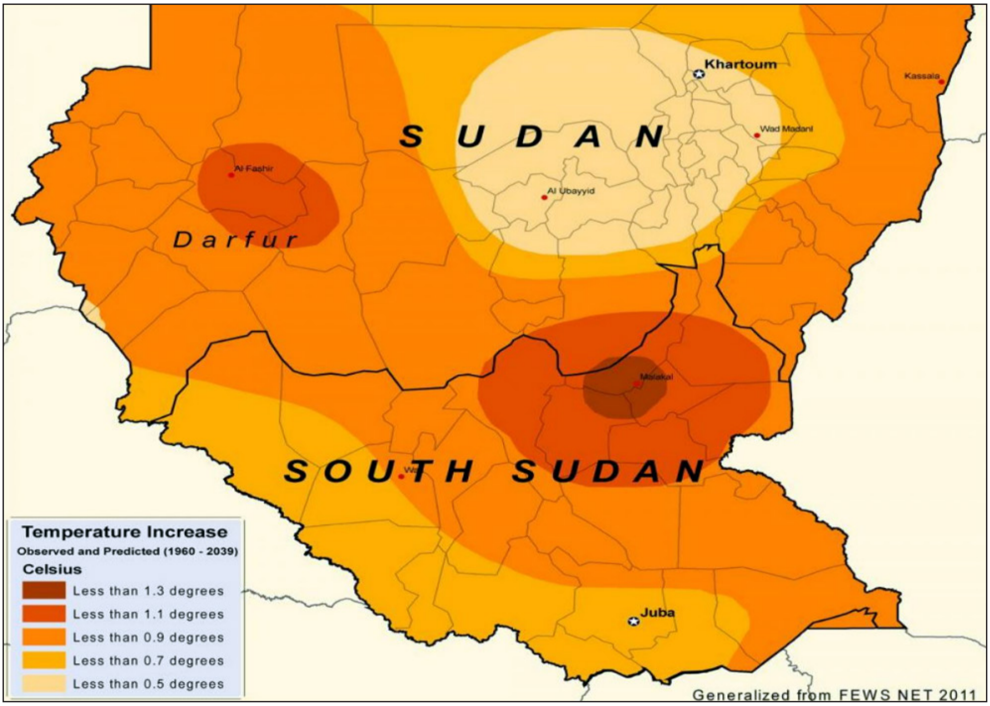
There is a significant increase in temperatures over the whole of Sudan, with a significant decrease in rainfall rates in the northern half of it. The correlation between temperatures and irregular rainfall confirms the frequent occurrence of droughts. In contrast to the assumption of a return to drought that lasted for a long period in the African Sahel region, the results for Sudan indicate a high level of drought. The frequency of occurrence of drought categories during the period 1975-2008 ranged from 44.1% - 70.6%, compared to frequencies that ranged between 8.8% - 40.0% for the period 1941-1974 (Elagib, et al. 2011). Climatic data for Sudanfor a period of 30-50 years, show an increase in temperature and a decrease in rainfall. It also confirms a change in the pattern of relative humidity, clouds, radiation, and evaporation, a trend that may accelerate environmental degradation and desertification in Sudan (Alvi, 1994).

Annual trends in average temperature during the period from 1950 to 2020 in Sudan show peaks of increase during each decade, and there is fluctuation in annual average temperatures during each decade of this time period (Figure 1). Likewise, important decadal trends appear during this period 1950 -2020, divided into three decades, increases in average temperatures (Figure 1). This is confirmed by the observed and expected temperature increase for the period 1960-2039(Figure 2), which ranged between less than 0.5 and 1.3 degrees Celsius. Before that, since the 1940s, there was an increase in annual temperatures and wet season by 0.076-0.20 and 0.082-0.29 degrees Celsius/decade (Elagib, et al. 2000). The period of greatest warmth in Sudan appears to be linked to the dissipation of rain that was recorded after the mid-1960s. A general increase in the coefficient of variation of monthly temperatures during the year was also observed, which is more significant in the northern and central locations of Sudan (Elagib, et al. (2000).

Figure 1: Annual trends in mean temperature with a significant decadal trend in Sudan 1950-2020



Source: https://climateknowledgeportal.worldbank.org/country/sudan/trends-variability-historical



Source: UNFCCC

Studies on climate change and land use/land cover along seasonal migration corridors for livestock in the Gedarief region in eastern Sudan have confirmed a degree of significant warming. There is an increase in irregularity and seasonality of rainfall, and increased drought conditions during the beginning and end of the wet season (Sulieman et al. 2012). Evapotranspiration over the Sudan responds more to heating and drought conditions, as it showed increasing rates, especially during the rainy season. It appears that the extent of the increase has decreased with the decrease in the period of sunshine, solar radiation, and the irregular behavior of wind speed. There have also been changes in the observations of monthly fluctuation during the year, which suggests an increase in the incidence of extremism (Elagib, et al. 2000).

Ayoub (1999) compared rainfall for a long period of time in four sub-regions in Sudan, where it became clear that the decrease in rainfall amounted to 30-40%. The parts of western Sudan (Kordofan and

Darfur) witnessed very large anomalies in rainfall compared to the central and eastern parts (Gedaref, Butana, and Damazin), and they suffered from great periods of intermittency compared to the eastern and central parts. The decadal rainfall averages showed lower than the average rainfall for the last three decades in these four sub-regions. Rain depletion was also characterized more severely in central, semi-arid Sudan, in the period 1921-1950 and 1956-1985 when the annual rainfall rate decreased by 15%, and there was a contraction in the length of the rainy season by three weeks, and the rain zones migrated towards the south by about 50 and 100 km.This is due more to the low frequency of rain events than to the low rainfall productivity associated with each “rain event” (Hulme, 1990).

The annual time series south of 16°N mostly follows the rainy season time series, with the exception of the zone north of it that shows a real change in the temperature time series. There are clear rising trends in the time series of wetness and hot seasons in the rest of the country, and their trends are characterized by rising. The periods 1941-1970 and 1951-1980 were also distinguished by their significant difference from the periods 1961-1990, 1971-2000, and 1981-2010, as they were the wettest. This was evidenced by the indicators of the beginning of a new increase in rainfall in the period 1981-2010 (Mohamed, 2018). Summer rains have decreased in western and southern Sudan by 10-20% since the mid-seventies, with the observed heating exceedingly only one degree Celsius, which is equivalent to (10-20%) (Mohamed, 2018).

It is likely that the temperature and wetness rates will rise over the Dinder River, which is sensitive to these two climate factors that are likely to rise in this century (Basheer et al. 2016). By so, the climate above it will become hotter and wetter and its expected flow will become very sensitive to changes in rain and temperature. It is expected to increase so that it positively affects the ecosystem of the Dinder River Park and not just the river.This may improve the process of ecological restoration of plant and animal habitats in it (Basheer et al. 2016). Similarly, the archive of satellite and aerial images of western Sudan has shown short-term trends during the period 1943-1994 in tree abundance despite many decades of drought in the region. Despite the return of plant population turnover, this is not yet considered an indicator of recent climate changes in this region (Schlesinger et al. 1996).

Environmental impacts of climate change in Sudan:

Climate changemanifested itself in the indicators of rising temperatures, fluctuations in rainfall, and repeated waves of drought, causing severe impacts on different life forms (Nadeau, et al. 2007; Ye, et al. 2018); and on different regions and social groups (Watson, et al. 1996), and has led to a decrease in natural vegetation, accelerating desertification (Fu, et al 2017),environmental degradation and loss of biodiversity (Wang, et al. 2017)aschanges in vegetation structure and land cover (Klein, et al. 2007), especially in dry regions (Yu, et al. 2018, Xie, et al. 2016). There is evidence that warming during the twentieth century has been faster than shifts in species ranges (Houghton, 1990), potentially leading to widespread loss of biodiversity (IPCC, 1996).

Drought areas in East Africa are expected to increase by 16%, 36%, and 54% under Representative Concentration Pathways (RCPs) and by 2.6, 4.5, and 8.5, respectivelyby the end of the twenty-first century (Gebremedhin et al. 2020).Also, since the end of the 1960s, the West African Sahel region (10-18 degrees north) has witnessed a continuous and often severe drought, and it is considered among the most extensive climate changes on a regional level and unquestioned over the last half-century (Bell et al 2006). Sudan as part of both these regions is not exceptional, and is considered the most vulnerable (Gebremedhin et al. 2020)as the observed climate change in Sudan has exacerbated drought conditions (Elagib et al. 2000). The interaction of endemic poverty, and environmental systems deterioration, complex disasters, conflicts, and the limited availability of capital, markets, infrastructure, and technology are essential to exacerbate climate change impacts in Sudan (Zakieldeen, 2009). Also, the key aspects of the vulnerability of Sudan's savanna range to drought including environmental fragility, institutional weakness, high levels of poverty and food insecurity, and economic and political instability, all of which have been exacerbated by climate change (Callo-Concha et al. 2013). Rapid population growth and the expansion of agriculture and nomadism under a changing climate budget could dramatically increase the number of "at-risk" citizens in Sudan in the next 20 years (Funk et al. 2011).

Various early studies predicted the decline of vegetation in most areas of Sudan (Stebbing, 1972). In western Sudan, Acacia "Hashab" trees grow as part of the agro-pastoral system, which has been able to resist for hundreds of years in Kordofan Governorate, where 70% of gum Arabic is produced. Gum Arabic production in Sudan deteriorated sharply after the long drought that extended from 1979 to 1985, as many trees were lost due to drought and pests. Farmers report that the deterioration in gum Arabic production is largely due to the "unfavorable" nature of social-economic relations, the role of which drought exacerbated and led to the deterioration of the production of the agricultural-forestry system. The inability to obtain a fair price at the local level and an overemphasis on cash economics to ignore the components of the "tree" have resulted in a system in which Gum Arabic gardens have flourished with intensive orchard cultivation by small farmers. The "Hashab" tree disappeared as soon as farmers were no longer able to care for it(Huntinger, 1993). Financial and business risks can have serious impacts on farmers' decisions and farm income. Farmers can also be more risk-efficient and obtain higher incomes by adopting more diversified agricultural systems and applying the proposed improved practices (Mustafa, 2006).

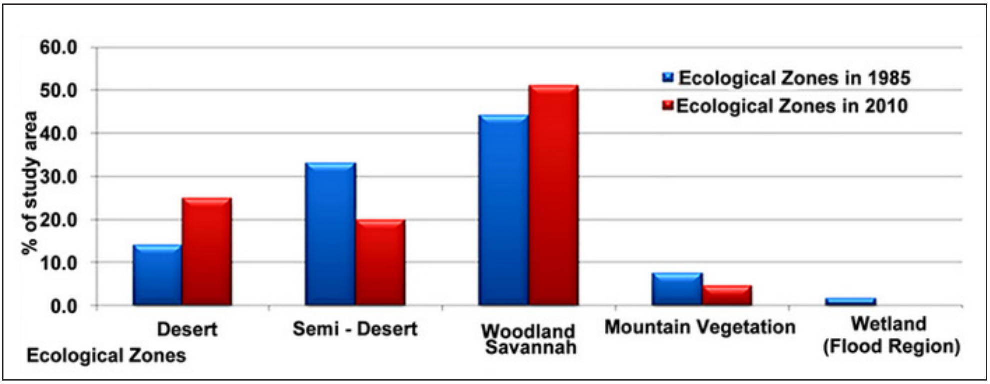
The Kordofan region contains diverse forest species (more than 180 species of trees and shrubs), both local and exotic. Threats to these forests include drought, soil factors, use of fire, grazing, expanding agriculture, illegal logging, lack of awareness about the problems of deforestation, and insufficient forest awareness. Genetic erosion has occurred in most parts of the natural forests in Kordofan (El Tahir et al. 2010). The central region of North Kordofan provides the necessary natural resources for “nomadic” agricultural and pastoral activities.The unjustified use of these resources has led to their degradation and destruction. Desertification also excluded much of the land from production at a time when the population and demand for land were increasing. Environmental damage also included water shortages and the change in the pattern and timing of seasonal rainfall, as collective grazing increased, which led to overgrazing, and increased logging for the purposes of making charcoal and building homes, where women are considered the most affected (Badri et al. 2000).

The decrease in the abundance of herbs in the Port Sudan area in 2020 AD can be attributed to the very high temperatures after 1998 AD (Loh et al. 2020). Similarly,more areas were affected by desertification and desert encroachment in the Abu Zabad locality in western Sudan(Abbaset al., 2018).Despite this, long-term desertification/the return of the growth of natural vegetation cover over time and space in the center of North Kordofan Statewas estimated and found that desertification during the last 21 years has helped the return of natural vegetation growth in the areas around rural villages (Dawelbait et al. 2012

Climate change in Sudan has led to the deterioration of the environmental ranges in the period between 1985 - 2020 (Figure 3), as for example, the desert range expanded by more than +11.0%, from 177,308 km2 in 1958 to 314,076 km2 in 2020 (Figure 3), and similarly the rest of the ecological ranges (+6.8% for semi-desert), except for the ranges of upland and wetland plants (Nadir et al. 2016). Various studies indicate the deterioration of about 120 million hectares of land, including 64 million hectares of different soil types to varying degrees (Ayoub, 1998).

There are many applied studies that help explain this deterioration as a result of climate change. In Dar es Salaam locality, North Darfur state, the percentage of crawling sand increased successively by 29% (868 km2), then to 36% (1035 km2), then to 39% (1132 km2) during the period from 1970-2018 (Al-Zubier et al. 2019). In North Kordofan State, the NDVI index for the degree of greenness of vegetation and its relationship to rainfall showed low values in three of the eight seasons under study (Elton et al. 2019), and the results confirmed that the sand on Khor Abu Habil advanced by 4% in 2000 and 13% in 2020. (Ahmed et al. 2022), and the Blue Nile forests deteriorated in the quality of trees, as many of the species that were prevalent in the past decreased and others disappeared, such as A. seyalvor fistula, and the area of these forests decreased from 14.7% in 1973 to 3.1% in In 2016 out of the total area of the region (Al-Zubier et al. 2020), and in the Ashaad and Setrab regions of the Red Sea State in Sudan, the vegetation area decreased from 192.38 square kilometers to 187.39 square kilometers and then to 148.59 square kilometers between the years 1987, 1999, and 2013, respectively(Al-Zubier et al. 2020), similarly, the Halba region in White Nile State lost 91% of its tree and forest cover, which represented 41% of its area, and the area of natural pastures decreased by 16.55% in the period between 1973-2014 (Wadi et al. 2017). In the Butana area, a peak of natural vegetation was found in the year 1850 AD, which had the ability to carry the natural vegetation, environmental imbalance began in 1970 AD, and the changes occurred during four successive stages, evident in the dynamic deterioration of the vegetation cover, the decrease in rainfall rates, and the decrease in the carrying capacity (Alredaisy et al. 2011), and likewise it became clear that the deterioration of acacia trees (Acacia) in the West Butana region is due to a decrease in annual rainfall rates, among other factors, including agricultural expansion, which contributed by 40% to it (Alredaisy et al. 2011).The instability of climate factors and the change in biological factors have led to the deterioration of soil resources and thus the scarcity of tree products in the Qadmabila area in Gedarief State (Idris et al. 2015).

Figure 3: Environmental ranges in 1985 and 2010



Source: Nadir et al. 2016

Land degradation and desertification processes have increased in arid and semi-arid environments in the last four decades (Salih et al. 2017). Land degradation can lead to climate change, as high temperatures, low rainfall, long periods of sunshine, cosmic radiation, and high rates of evaporation-transpiration, especially during the wet season, have been observed, in addition to changes in the oscillation of annual and monthly observations (Elagib et al. 2000). Mechanized agriculture projects in the Gedariefregion are considered a major cause of environmental degradation and land loss, in addition to environmental complications such as drought. Forests have turned into agricultural lands, accompanied by unorganized cutting, which is considered the main factor contributing to land degradation in the Gedarief region. In addition, contradictory sectoral policies affect land ownership (Glover et al. 2012). In light of such factors, there is evidence that confirms the consequences of dry farming of lands in the Gedarief region for decades, which led to rapid changes in land use and land cover due to agricultural expansion, government policies, and drought.

The agricultural sector suffers from climate fluctuations. This situation worsened further after the discovery of oil and the focus on investment and petroleum-related industries (Mahgoub, 2014).The negative impact of the potential climate change falls on food availability and connectivity in Sudan. The most affected are the poor familiesalong with the deterioration in the country's economic performance (Sassi et al. 2013). Climatic changesignificantlyled to changes in the pattern of land use, land cover, and soil physical and chemical properties. These changes contributed to land degradation and low soil productivity (Biro et al. 2013). In Sudan, deep plowing and leveling of the surface soil in rain-fed agricultural areas increased its exposure to wind erosion. This has caused a decline in soil fertility and the formation of sand dunes in some places. The impacts of these practices on the natural resource base have included environmental degradation, food insecurity, and a sharp increase in income inequality among Sudanese producers (Abadi et al. 2013).

There are important changes in climate conditions, soil characteristics, and natural vegetation in the Butana region, as the size distribution of soil particles changed to a high degree, especially in the silt layer, and a slight change occurred in alkalinity - acidity (Meheissi, et al. 2010). The Butana region was affected by the fluctuation of Climate change in renewing its natural resources, including the soil resource, as it is characterized by a “soft” balance between climate and ecosystem, which is what characterizes the Sudanese Sahel region, of which it is a part (Elhag et al. 2009). Likewise, the Gash Delta scheme has been affected by climate fluctuations, on which a large number of ethnic groups rely to live and be self-sufficient, and have different production strategies, some more successful than others. Since the 1980s, a clear deterioration in the irrigation system in this scheme began with a decrease in the areas available for agriculture and a general deterioration in the natural production base, which affected these ethnic groups (Kirby, 2001).

Climate change in Sudan has also caused a shortage of drinking water in its arid and semi-arid parts. It began to take a critical situation in the 1940s of the last century when population density increased around water sources. Consequently, there were increased concentrations of humans and animals, environmental deterioration, and removalof vegetation. The government adopted a number of ambitious projects to improve rural water sources in Sudan, which differ from one region to another. In dry areas, improving these sources may mean increasing the amount of water, and in less dry areas it means more than just water quality. The imbalance between the amount of water required for healthy living and real consumption is considered the central problem of rural water supply in Sudan (Mohamed et al. 1985).

Conclusion:

This research worked to reviewclimate change indicators and their environmental impacts in Sudan. Climate change occurred in early geological periods and is still occurring there as there wasan increase in temperature and a decrease in rainfall; a change in the pattern of relative humidity, clouds, radiation, and evaporation, rainfall depletion; a contraction in the length of the rainy season; and a migration of the rain zones southwards. The impacts are quite varied including, not exclusively, the deterioration in landsand soils; the renewal of natural resources; the expansion of the desert area, semi-desert, and dry savannah; the Gum Arabic production; the grain production; the tree scarcity; and the tree products. Importantly, there is environmental conflict over resources (Verhoeven, 2011).

Combating the impacts of climate change in Sudan requires an effective membershipin the international action systems combating climate change. Since Sudan does not differ from other developing countries in its high degree of exposure to climate fluctuation and change (Zakieldeen, 2009), there is a need for regional cooperationto keep pace with developments in climate change information, and a local line of combating programs that consider the human factor including visions and aspirations of the contributors to how these combating programs integrate together (Davies, 1986), not the authoritarian visions.

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4

Red Sea Basin Ecosystem Characteristics and Threats

4

Red Sea Basin Ecosystem Characteristics and Threats

Ecosystems of various types represent balanced ecological habitats, such that disruption of one of their components leads to disruption of the entire ecosystem. The Red Sea Basin is considered a distinct ecosystem for reasons related to its living components and geographical and geological characteristics. Exploitation of marine natural resources, rapid population growth, military conflicts, and climate change has created many threats that may cause it to lose its natural characteristics. This requires knowledge of these characteristics and threats to work towards its sustainability, which made them the objectives of this study, which will add environmental-geographic information that will help the countries of the Red Sea Basin in developing joint plans and strategies to exploit it in ways and sustain it. These objectives emphasize the importance of this current and future study, which relied as sources on the results of studies and research conducted during successive decades in the Red Sea Basin, and followed methods of description, analysis, induction, and deduction, committed to achieving its objectives.

Theoretical framework:

An ecosystem is defined as an area of land and the living organisms that produce, consume, and decompose it, and its non-living, organic and inorganic components. The living organisms in the ecosystem are linked by nutritional relationships and interact with the non-living components until they achieve a state of stability or environmental balance, which is the maintenance of the components and elements of the ecosystem in their original state (Al-Dwikat, 2019). The ecosystem varies in area and size, from a small pond to vast areas in deserts. The term environmental complex is applied to all the elements and components of the environment, the systemic relationships that prevail between them, and the environmental problems related to the deterioration of the biosphere (Al-Barjawi, 2012). The marine ecosystem is characterized by its salt water content (Wikipedia, 2020), and includes the oceans, seas, bays, lagoons, major water bodies, and lands before the sea, and all the interactions and interactions that occur between them and the atmosphere (DMAT, 2005), in addition to the rocky systems located in the tidal ranges, Hot vents, the sea floor, and the community of living organisms associated with it and their natural environment (Wikipedia, 2020). Seabirds are defined as species that depend on the marine environment for their food, reproduction, and transportation, and are not seen in areas other than marine ones.

Physical characteristics of the Red Sea basin ecosystem:

The Red Sea Basin separates the continent of Africa from the Arabian Peninsula and opens to the Indian Ocean through the Gulf of Aden (Figure 1). It starts from Bab al-Mandab in a north-west direction until it is divided into the Gulfs of Aqaba and Suez. The maximum limit of the Gulf of Aqaba reaches latitude 29 0 north, while the Gulf of Suez reaches latitude 030 north. Its maximum breadth is at latitude 17 0 north, then it narrows slightly and regularly towards the Gulfs of Aqaba and Suez, and its area is about 440 thousand km2 (Buist, 1854).

The Red Sea took this position as a result of the Earth’s crust being exposed to tensile forces that caused the start of basalt volcanism in Ethiopia, northeastern Sudan, and southwestern Yemen about 31 million years ago, followed by rhyolitic volcanism that spread toward the north and continued for about 25 million years. Most of the Red Sea and the Gulf of Aden were at sea level (Drake et al., 1964). The formation of marine-tectonic deposits began over the continental crust in the middle of the Gulf of Aden, the formation of a small refractive basin in the Eritrean Red Sea, expansion and uplift in the Afar region, accompanied by processes of volcanism, expansion, uplift and sedimentation, which led to an increase in water depths and a change in sedimentation to a type dominated by limestone, about 25 million years ago. year (Bosworth et al., 2005). The natural folding accompanying these processes caused the sea floor to expand and thus enter the Red Sea in the early stages of continental divergence (Lowell et al., 1972). The deep groove in the middle of the Red Sea represents a rift filled with basic and igneous materials, positive Bouguer gravity anomalies, large magnetic anomalies, and a seismic velocity of 7.1 km/s (Drake etal., 1964).

The morphology and tectonic movements resulting from these movements differ along the Red Sea, despite the continuation of subterranean movements between the continent of Africa and the Arabian Peninsula (Cochran, 1983). The main depression cuts a deep axis south of latitude 21 0 north. It is the result of the expansion of the Red Sea floor during the past four million years and is linked to with large magnetic anomalies and high heat flow. North of latitude 25 0 north, there is no axial depression, and the bottom of the main depression takes the form of an irregular refraction (Cochran, 1983). The Red Sea basin has witnessed historical periods of drought, high salinity, and intermittent isolation (DIBattista et al., 2016), and it contains dozens of highly saline submerged lakes (Antunes et al, 2011), and many islands and archipelagos include Tiran, Sanafir, Safaga, Wadi al-Jamal, Az-Zabarjad, Halayeb, Dahlak, and Farasan. In general, the Red Sea is considered a relatively modern tectonic rift basin surrounded by desert and separating the African-Asian dry zone.

In the northern part of the Red Sea Basin, the winds blow from the northwest to the north-northwest side, while to the south of latitude 019 north, the change in wind gusts is linked to the Indian monsoon, which comes from the south-southwest side in the winter and the north-northwest side in the summer. The interference of westerly winds in the middle of the troposphere and the Red Sea terrain is considered the main factor in the formation of the Red Sea Depression (Krichak et al., 1997). Surface and intermediate water masses during summer circulation show spatial variations in their properties as a result of mixing processes and circular movement of waters opposing the direction of the main current (Sofianos et al., 2007). The Red Sea wind convergence area moves northward during the warm phase of the southern oscillation of the phenomenon

Figure 1: Location and topography of the Red Sea Basin

Source: 0ntheworldmap.co

Characteristics of the living components of the Red Sea basin ecosystem:

The Red Sea contains a rich biota (DIBattista et al, 2016b) with different types of organisms, including fish, microorganisms, seabirds, coral reefs, mangroves, and shallow coastline organisms. This unique biodiversity resulted from geological and climatic factors in addition to the isolation to which the Red Sea was exposed, which led to the separation of animal life in the northern part of it from that in the southern part, which created a strong barrier that caused the rise of cold, nutrient-rich water at the borders of the Gulf of Aden and the Arabian Sea (DiBattisa et al. al.,2016). Sponges, elastic corals and algae are the most common and are characterized by distinct and unique structural shapes and exhibit many biological activities that provide food for marine organisms because they contain organically active substances (El-Ezz et al., 2017).

The Red Sea contains a great diversity of pelagic and deep-sea microorganisms that are part of the food chain for a number of organisms, and some of them, such as the pteropods coccolithophordis, were subject to disappearance due to the high salinity in the Red Sea during the Late Quaternary Glacial (Winter et al., 1983). The bacterial communities associated with sponges are characterized by the ability to maintain their organization despite their differences according to the types of sponges (Lee et al., 2011), and there are types of them that have the ability to resist environmental disturbances, which is reflected in the microbial communities in which they live (Lee et al., 2011). Some major benthic organisms occupy hard and soft corals and algae in the northern part of the Gulf of Eilat (Benayahu et al., 1981). Microbes modified some of their genes to be able to live and grow in extremely hot and salty water (Asharq Al-Awsat, 2018). There are some areas in the central Red Sea free of plaquenton when the sea is at its lowest levels due to high salinity caused by the total isolation from the Indian Ocean, while the Gulf of Aqaba and the southern part of the Red Sea have maintained good survival conditions (DiBattisa et al., 2016).

There are four regions and seasons covering the main patterns of pelagic phytoplankton production in the Red Sea Basin (Raitsos et al., 2013). The coccolithophore community in the Red Sea, when compared to the community of the marginal Pacific seas, appears very similar, especially in areas of shallow coastal waters, but it is completely different in some aspects from the communities of the open sea (Okada et al., 1975). There is also great diversity of local microbiological communities in the Red Sea, some of which are toxic (Antunes et al, 2011). The cyanobacterium Trichodesmium, which inhabits the open seas, consists only of filamentous trichomes, but includes some species related to some organisms such as bacteria, diatoms, dinoflagellates, hydrozoanas, copepods, and single-celled organisms (O'Neil et al., 1992).

The updated list of Red Sea fish (Table 1) shows 1,078 species belonging to 154 families and 25 orders (Golani et al., 2010), and about 1,284 species are endemic to its deep waters, the most important of which is the butterfly fish family, which includes 14 species (Al-Sayed, 2006). Because of the high proportion of endemic fish in its littoral coastal areas, the Red Sea and the Gulf of Aden were established as a separate faunal geographical unit, and ichthyofaua also proved that the Red Sea is a distinct region (Klausewitz, 1989). On the Jordanian coast of the Gulf of Aqaba, the total number of fish reached 705 species belonging to 109 families, 82.8% of which belong to demersal fish and the rest to oceanic fish. Endemic fish constitute 12.8% of the total fish recorded in the Red Sea and the Gulf of Aden (Khalaf, 2004).

Table 1: Some Fish community of Red Sea

Scientific Name	English Name
Rhincodontidae	whale shark
Stegostomatidae	Zebra shark
Ginglymostomatidae	Nurse Shark
Sphyrnidae	Hammerhead Shark
Lamnidae	Mackerel Shark
Alopiidae	Thresher Shark
Myliobatoidei	Stingray
Muraenidae	Moray eel
Ophichthidae	snake Eel
Synodontidae	Lizardfish
Scorpaenidae	scorpionfish
Carangidae	Jack and Trevally
Coryphaenidae	Dolphinfish
Lethrinidae	Emperor
Mugilidae	mullet
Amphiprioninae	Anemonefish
Scaridae	Parrotfish
Scombridae	Tuna and Mackerel
Chelonioidea	sea turtles
Actiniaria – Boloceroididae	sea anemone
Mollusca	Molluscs
Crustacea	Crustaceans
Brachyura	crabs
Asteroidea	sea stars
Holothuroidea	sea cucumbers

Source: The Free Encyclopedia 2019

Regarding the patterns, distribution and differences in the structure of the butterfly fish population (Chaetodonitidae) and the angel fish (Pomacanthidae), there are two species out of the seven endemic species that are limited to the central and northern Red Sea, and two other non-endemic species in the Gulf of Aden. The richness and abundance of butterfly fish is greatest in the central Red Sea and decreases towards the north and south and is consistent. Its spatial aggregation structure in most regions, but there is a major change in its abundance and composition between the central and northern Red Sea and the Gulf of Aden (Roberts et al. 1992). Pomacentrid fish, which inhabit coral formations along the Red Sea coast on the Sinai Peninsula, constitute a distinct group of species (Fishelson et al., 1974). Amphirin bicinctus, Dasycyllus aruanus, D. marginatus, Pomacentrus trichourus are considered suitable for shallow coral areas backreef, while Pomacentrus sulfurous, Abudefuf melanopus, A.melas along the rear-reef wall, and the coral reef stream is dominated by Pomacentrus albicaudatus, Abudefduf lacrymatus, A. leucozona, A. annulatus, and the front of the reef is occupied by Abudefduf saxatilis, A. sexfasciatus, A. leucogaster (Fishelson et al., 1974). There are also about twenty-two species of sea cucumber, two species in coastal Egypt and ten in the Red Sea sector, which differ in their vital activity according to biological habitats (Lawrence et al., 2010).

The Red Sea contains marine, coastal and mountainous environments that are suitable for migratory and resident birds (Table 2). Some bird species are associated only with the Red Sea, although a few of them have partially adapted to the conditions of the islands where they stay for part of the year. These seabirds are considered long-lived birds, with the average lifespan of some of them being 15 years, others 25 years, and some 35 years. They lay a single egg, 80% of which are laid during the summer months on sand or gravel, and they build very simple nests of dry seaweed and some twigs. Many of the Red Sea islands are located in the main path of migratory birds during the spring (coming) and fall (return) seasons from Europe to Africa and vice versa (Arafa, 2017), especially the southern islands of the Red Sea such as Farasan (PERSGA, 2019). Some seabirds migrate internally, and some migrate outside the region after the breeding season ends. There are subspecies that inhabit the northwestern Indian Ocean, and their numbers are very large here. It provides wet, low-lying coastal areas and adjacent shallow water.

Table (2): Characteristics of some Birds species and habitat of Red Sea Basin

1-	Phaeton aethereus indicus Red - billed Tropicbird Endemic - length 48 cm - few in number - rocky islands for breeding - nests singly or in groups between rocks and inside cracks.
2-	Sula leucogaster plotus Brown Booby is endemic - found on most islands in small numbers - nests directly on the ground of algae and crustacean shells.
3-	Larus hemprichil Sooty Gull is endemic and found nowhere else - length 44 cm - near the beach, fishermen's sites and waste.
4-	Larus leucophthalmus White-eyed Gull is endemic and found nowhere else - Length 40 cm - Endangered - Nests on rocky or sandy islands - Nests are made of moss, shrub sticks, feathers and snails.
5-	Sterna bergii Swift Tern is endemic - large in size - nests in large colonies - gathers on islands and sandy beaches - feeds on fish, squid, crabs, turtles and chicks of other birds.
6-	Sterna bengalensis Lesser-crested Tern is endemic - length 46 cm - nests in close colonies of 8-11 nests per square meter - gathers on sandy coasts and islands - feeds on pelagic fish.
7-	Sterna repressa White-cheeked Tern is endemic - it nests on sandy and coral islands and inshore islands - it gathers in widely separated colonies.
8-	Sterna anaethertus Bridled Tern is endemic and widespread on islands far from the coast. Length 46 cm. It nests on sandy and rocky islands, under cliffs or under rocks. It feeds on pelagic fish.
9-	Anous stolidus Brown Nodd is endemic - length 46 cm - found on most of the Red Sea islands that are rocky or with dense vegetation - nests in colonies.

Source: Marine and Ocean Sciences. 2011. https://marinesciences1.blogspot.com

The coral reefs and islands provide an ideal natural habitat for a large number of seabirds. The regional importance of some of the islands extending along the coast of Saudi Arabia on the Red Sea became clear for the breeding of seabirds, which number up to 66,500 of 21 species that are more abundant in its south compared to its north (Alsuhaibany, 1999), in addition to twenty species of them on eleven islands in the northern region, and twenty-three species of them. On eight islands in the southern region, in addition to twenty-three species, including three mangrove sites (Abdullah, 2018), in addition to thirty-three species, excluding migratory birds in the Dahlak Archipelago (Clapham 1964). Waders, herons and raptors can be seen on the Red Sea coast, shallow waters and mangrove swamps and are not true seabirds (Evans, 1987).

Coral reefs give the Red Sea the character of the most diverse marine ecosystem (Raitsos et al., 2013). There are 346 species, including nineteen endemic species (DIBattista et al, 2016 b), close to the coast and along the margins of fan deltas and erosional plains. It developed under semi-arid climate conditions in which clastic sedimentation systems dominate the environment, morphology, and internal structure of coral reefs rather than the structural growth of coral frameworks, as is the case in natural coral environments (Hayward, 1982). The environmental conditions of the Red Sea are also considered ideal for the formation of hard coral reefs that Its annual growth rate varies between one centimeter and 20 or 25 cm. There is a successive increase in the diversity of hermatypic corals in waters shallow to a depth of 30 cm and in sloping areas more than in flat areas due to the accumulation of sediments in them (Loya, 1972).

Mangroves are spread on the coasts and islands of the Red Sea basin, such as the Gulf of Suez archipelago, Tiran, Sanafir, and Halayeb (Antunes et al, 2011). It includes about seventy species belonging to twenty different families, the most widespread of which is the Avicennia marina species on the Red Sea coast (PERSGA, 2019). Its growth and qualitative differences increase along the Saudi coast as we head south, where it tolerates salinity, lack of oxygen, and relatively better growing conditions (Saifullah, 1996). The flora and fauna associated with the mangrove ecosystem on this coast are exposed to harsh climatic conditions such as low levels of nutrients, high salinity and a hard bottom dominated by mangrove trees. Mangrove seeds in the Jazan region showed higher price values than those found in northern Saudi Arabia due to higher soil moisture and containing more organic materials (Khafaji, 1990). The rate of vegetative release of mangroves in the Jizan region is similar to other locations in the world (Saifullah, 1996), and is characterized by its stability throughout the year with an increase during the summer (Khafaji et al., 1991).

Interactions of ecosystem components in the Red Sea Basin:

The overlapping components of the Red Sea Basin ecosystem take many forms . During the southwestern monsoon season, coming from the tropical region over the Indian Ocean, from May to September, the cold water it carries causes clear environmental changes in the southeastern Arabian Sea (Bailey R, 1966), including a significant increase in the production of organic matter that reaches the Red Sea to benefit from it. Living organisms (Portik et al., 2012), which helps increase the degree of endemism, abundance, and high proportion of migratory birds. Therefore, the Red Sea has a profound biogeographical impact on organisms associated with their African-Asian distribution, resulting in complex forms of biotic mixing (Portik et al., 2012), and the deep salt ponds with complex physicochemical properties make it the most hospitable environment for living organisms, and it is considered Its submerged hypersaline lakes have microbial ecosystems (Antunes et al, 2011).

Mangrove settles soil, thus protecting beaches from erosion, enhances the diversity of living communities, and is a source of nutrients that enrich primary productivity in the marine environment (PERSGA, 2019). In the archipelago at the entrance to the Gulf of Suez and the islands of Tiran, Sanafir, and Halayeb, the mangrove is considered a natural habitat for a number of birds that build their nests on it, and for a variety of crustacean animals (Antunes et al, 2011). The arrival of birds to breed in the summer months in the Red Sea basin means that they are able to withstand high temperatures and adapt, and their collection provides some organic waste that provides fertilizer for organisms suspended in sea water, such as blackton, and food for coral and some fish (Shubraq, 2017). Seabird droppings also provide an important source of nutrition for marine plankton, which in turn is a source of food for young fish and shrimp.

The richness and abundance of butterflyfishes in the central Red Sea is consistent with coral growth and diversity and with hard coral cover (Roberts et al. 1992). The highest diversity and species richness of the fish community is found above the coral interface and there is little above the small ridges and seagrass sand bottom (Tuvia et al., 1983). There are twenty-three species of macroalgae associated with mangrove plants in the area adjacent to the cities of Hurghada and Safaga, which means that its areas provide an environment that allows weak algae to grow at high rates compared to open coastal areas (EL-Sharouny et al., 2001). Plants attached to the mangrove and benthic algae accompanying its ecosystem are also considered another source to compensate for the lack of food in the Red Sea environment, as these organisms perform photosynthesis, which benefits the mangrove (Saifullah, 1996). There are several similarities between the spatial distribution and abundance of chaetodontid fish and the diversity of the coral community and the substratum coverage of its colonies, suggesting the existence of strong relationships between them (Navarro et al., 1989). Reigl et al. 2000 confirmed this relationship between chaetodontid fish and coral communities in the Gulf of Aqaba, which has broken uplands and rugged valleys (Melamid, 1957), where he observed a clear ecological correspondence along gradients of depth and hydrodynamic exposure that gradually change with increasing depth and are controlled by bottom topography of the Red Sea in this area. The fauna and flora of the Red Sea show environmental fluctuations ranging from slight to high, high rates of endemism of coral reef organisms, and variable degrees of invasiveness within the Gulf of Aden (DIBattista et al, 2016 b). Benthic coral algae reduce the availability of carbon dioxide in waters close to coral environments, resulting in rapid microbial degradation. The main benthic organisms have movement mechanisms that help corals regulate the size of their community and benefit greatly from successfully competing for the available space with other benthic organisms (Benayahu et al., 1981).

Sea grasses, whose flat surfaces extend along the shallow sides of the Red Sea and which include eleven species, are considered one of the richest and most productive marine ecosystems and are considered an important source of food and shelter for young fish and crustaceans. (Wild et al., 2010) confirms the presence of forty-nine species of marine invertebrates that make marine grasses their home in the Gulf of Aqaba, and use cyanobacterium, Trichodesmium, bacteria, diatoms, dinoflagellates, hydrozoanas, copepods, and single-celled organisms, Trichodesmium, as a material on which to feed and grow surface organisms. Thus, Trichodesmium helps in understanding carbon and nitrogen inputs and outputs in the open ocean (O'Neil et al., 1992).

Guca (1994) identified six new species of Red Sea fish, adding to the twenty species previously known along the Antiochian coast, as a result of the digging of the Suez Canal and the movement of some of its fish to the eastern Mediterranean (Kimor, 1972), which caused a profound change in the ecosystem there. (Golani, 1998), which is characterized by low primary productivity and few seabirds compared to the Western Mediterranean, which is comparable to the Red Sea (Zotier et al. 2003), as these migratory organisms will need new mechanisms to adapt to the Eastern Mediterranean environment. Due to the connection of the Red Sea with the Arabian Sea, rich and nutritious water enters it through Bab al-Mandab, strongly during the flow of the monsoon winds in the winter, and weakly during the summer season, where it moves to the depths of the water to become part of it, consisting of two or three layers that alternate seasonally at Bab al-Mandab (Arz, et al. 2003).

Threats to the ecosystem of the Red Sea Basin:

The Red Sea Basin is characterized by its uniqueness and high environmental fragility (Edwards, 2013), aided by its semi-enclosed nature, its unique biodiversity (Abu Qdais, 2008), its geographical location and its geological history (Edwards, 2013). This is confirmed by studies conducted on its ecosystem, amounting to seventy-six subjects, forty-five of which reported the presence of devastating effects of pollution of various types (Gladstone et al, 2013). Seabirds are exposed to the dangers of predators and introduced species, such as mice and cats, collecting eggs, disturbing fishermen and visitors during the nesting season, and high mortality rates among them as a result of petroleum oil spills (Leighton, 1993). As for fish, they are exposed to the dangers of overfishing and marine pollution, as the updated list of Red Sea fish confirmed a much smaller number of their species compared to the last list issued in 1994 (Golani et al., 2010). There are significant changes in the richness and abundance of endemic fish species along 1,100 km of the Saudi coastline (Guca, 1994). The pumping of deep Red Sea mud, which contains commercial quantities of iron, has raised questions about its impact on the deep central part of the Red Sea and the resulting environmental risks (Karbe, 1987). The discovery of sedimentary iron and heavy metal deposits in the middle of the Red Sea confirms the continued activity of the processes that control its deposition (Miller et al., 1966). Deep mining in the Red Sea adds heavy metals, liquid compounds, and toxic chemical compounds such as zinc, copper, cadium, and mercury, which causes major changes in the microelement composition of water masses (Abu Gideiri, 1984). Phosphate mining in the Saqqara-Qusayr region resulted in an increase in the activity rate of 226Ra/228 and in a large flow of 226Ra towards Shuqair in the north and Saqqara in the south (Mamoney, 2004). (Walker et al., 1982) observed an increase in the death of corals of the Stylophora type in the polluted area in the Gulf of Aqaba at a rate ranging between 4-5 times compared to the protected area due to phosphate dust while loading it on ships, which reduces light intensity, which hinders the process of calcification of coral reefs. The rate of pollution of its areas in this bay also increases with sewage discharge (Walker et al., 1982). As for the port of Port Sudan, the values of 226R and 210Po are relatively high, and the activity of Cs is 137 in the sediment sample taken from it compared to the sediment sample from the edges of the coral reefs adjacent to it (Sam et al., 1998). Mangrove trees in Yemen face the same problem, in addition to logging, fish farming projects, tourism, overgrazing, dumping of solid waste, and backfilling operations (Nagi et al., 2013). The impact of pollution due to human activity on coral reefs in the Red Sea increases the possibility that their environment will not return to its original form (Loya, 1976), especially since differences in the temperature of coral shelves in the Red Sea have been documented (Davis et al., 2001). Oil exploration and exploitation and petroleum industries are also considered sources of pollution in the Red Sea (Mamoney, 2004), as (Khalaf et al., 2002) observed the instability of the nutritional composition of fish from the Jordanian coast on the Red Sea near industrial areas, unlike sites devoid of industries. This is due to the fact that these activities work to deposit chemical and organic compounds that threaten ecosystems, and this is confirmed by (Bresler et al., 1999), who found a decrease in the ability of mollusks in these polluted sites. Ships crossing the Red Sea carry cargo, some of which are toxic or harmful to marine life, and types of toxic organisms enter from distant areas, leaving negative effects on coral reefs, beaches, fish farms, and mangroves (Coakley et al., 2001). The discharge of organic materials into seagrass, seaweed, and marsh environments from neighboring ecosystems also results in some aspects of environmental poverty (Saifullah, 1996), including the project to divert water from the Red Sea to the Dead Sea to produce desalinated water, which depends on the disposal of salty water and cleaning and treatment solutions and chemicals which greatly affect the fragile marine environment of the Gulf of Aqaba (Abu Qdais, 2008). The implementation of the proposed Mediterranean-Dead Sea Canal project will also change the biology, chemistry, and physics of the Dead Sea and its surface biological environment (Beyth, 2007). It is expected that a mutual environmental impact will occur between Red Sea organisms and Mediterranean organisms as a result of the migration of some Red Sea organisms to the eastern Mediterranean (Golani D. 1998). Tourist destinations also contribute to the pollution of the Red Sea (Khalaf et al., 2002), adding significant amounts of plastic waste (LEW, 2013) and chemical and organic compounds (Bresler et al., 1999).

Political conflict and conflict over natural resources add a major threat to the ecosystem of the Red Sea Basin (Klare, 2001), as happened in the Horn of Africa, which included Somalia, Kenya, Ethiopia, and Djibouti, so that it became an international and regional conflict (Makinda, 1982). The search for securing fresh water for countries such as Jordan, Palestine, and Israel through the establishment of the Red Sea-Dead Sea Canal project is considered another threat (El-Anis, 2013), in addition to the conflict between Eritrea and Yemen over the Hanish Archipelago, which is rich in fish and diving opportunities (Westing, 1996). Eritrea and Ethiopia because it is a country closed from the sea around the port of Assab, which belonged to Eritrea after its independence from Ethiopia (Begashaw, no date).

Climate change is expected to have wide-ranging impacts on biodiversity, increasing extinction rates, biological differences between species, and increased rates of fragility (Foden et al. 2013). The salinity of the Red Sea is characterized by high sensitivity to global sea surface changes due to its limited exchange with the Indian Ocean (Arz, et al., 2003). The stability and resilience of coral reefs in the coming decades is also uncertain due to global warming, as the water temperature of the Red Sea has risen sharply by 0.7°C since 1994 (Dhani, 2011), and recurring events of erosion and washing will reduce the resilience of these important ecosystems (Fine et al., 2013), along with other natural factors such as the eruption of volcanoes, influence the future of the Red Sea basin ecosystem. The temperature dropped significantly in the Middle East and caused the vertical mixing of water in the Gulf of Aqaba to reach > 850 metres, where huge algae and phytoplankton were activated, which formed a thick carpet that covered the coral reefs located below, leading to their death. This was the Mount Pinatubo volcano in the Philippines in 1992 (Genin et al., 1995). The hot blob in the North Pacific between 2013 AD and 2015 AD also caused the loss of plankton, fish, and marine mammals at high rates (Carrington, 2020).

Planning indicators for the sustainability of the ecosystem of the Red Sea BasinThe planning indicators for the sustainability of the ecosystem of the Red Sea Basin are linked to three proposed axes:

1- The focus of scientific research: and its planning indicators are:

• Assessing the environmental vulnerability of the Red Sea Basin,

• Modeling the distribution of life species to cover some knowledge vacancies in some parts of it (Almalki et al., 2015),

• Identify the main refuges for some types of living organisms. The Gulf of Aqaba, for example, harbors selected coral species that are less susceptible to thermal stress (Fine et al., 2013),

• Identifying suitable habitats for species and benefiting from them to strengthen and support the plans and strategies developed at the level of the basin countries or individual countries.

• Modeling endangered plant and animal species,

• Modeling climate change to estimate its expected biological impacts and associated risks,

• Assess the expected adaptive capacities of plant and animal species (Foden et al. 2013),

• Coordination to conduct practical research in the form of regional research projects among the countries of the Basin in cooperation with various international organizations.

2- Education axis: Its planning indicators are:

• Use possible methods to educate and teach people the value of diversity and marine life,

• Support marine-environmental awareness by including it in recreational plans, activities and programmes.

• Direct exposure to the underwater world in recreational sites through the sport of diving, which may profoundly change an individual's perception and attitudes toward marine life and its conservation (LEW, 2013),

• Introducing environmental education curricula into school curricula.

3- The axis of environmental planning for its natural components: Its planning indicators are:

• Building databases and providing tools for analyzing the unique spatial characteristics of the Red Sea Basin,

• Evaluating development projects by considering environmental planning to ensure that the efforts made are conducted in an organized and planned manner so as not to harm organisms, which contributes to the preservation of biological diversity.

• Supporting environmental planning by using and applying various environmental protection tools and means,

• Developing specific environmental plans that deal with solving a specific environmental problem,

• Planning to use environmentally friendly technology for safe disposal of waste,

• Efficient energy use, reducing energy waste, and searching for alternative sources.

• Integration of administrative aspects between the countries bordering the Red Sea Basin, The success of these axes requires regional cooperation between the basin countries by allocating sufficient budgets, joint scientific and technical exchange, and cooperation with international scientific organizations related to marine environments.

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5

Anthropogenic factors exacerbating high siltation And mesquite expansion in Toker Delta, Eastern Sudan

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The influence of anthropogenic factors on agricultural systems is serious as the physical ones, and even more serious when irrigation systems depend solely on mountainous torrential rivers that are usually heavily loaded with sediments and forming inland deltas. Successive depositions would uplift delta base level, if irrigation system is improperly working which would eventually cause difficulties into mainstreaming of water for efficient irrigation. High siltation rates are serious in rivers of Mississippi and Colorado (GSA, 2011), Yellow River in China (Changxing, 2005), Black Warrior River (Black Warrior Riverkeeper, 2007), Himalayan region (Rinzin, et al., 2005), catchment area of River Niger Basin which had reduced from about 2,100,000 Km^2 to about 1,500,000 Km^2 (Olomoda. 2003). In Sudan, the reservoirs on the River Nile, the Blue and Atbara Rivers, River Gash are subjected to high siltation rates to the extent that it has threatened their primary purposes (UNESCO, no date; Bashar et al., 2005).

Agricultural lands are also vulnerable to harmful grass and trees invasion and also need to be managed properly. Among many threatening invading trees is Mesquite (Prosopis spp.). It is invading

India, Pakistan, South Africa, Egypt, Kuwait, Australia, U.S.A. (Hawaii), and Brazil, (Kay, et al., 2007), southern Arizona (Arizona Board of Regents. 2009), Western Australia (Robinson, 2008), semi-arid regions of northern Mexico and the southwestern USA (Brunel, 2009), upper San Pedro River watershed, which extends from northern Sonora (Mexico) to southeastern Arizona (Brunel, 2009), covers almost one million hectares of Australian land with the potential to cover 70% of mainland Australia (EKSA, 2010), the Rusizi floodplain and delta (IUCN.2010), Baringo District of the Rift Valley, Kenya (Okello,2008). Mesquite seeds requite a period of incubation into the intestine of an animal which ultimately being deposited into excrete as the mechanical mean for seed transmission. Mesquite usually reach 18 m height, roots grow deeply downwards in search for water up to 50.0-meters and animals avoid eating its sour green parts at early growth stage. The study on Mesquite management in Kassala State, eastern Sudan, concluded that "mesquite invaded valuable agricultural lands and sometimes grows into impenetrable thickets causing enormous problems to farmers and agricultural managers" (Abdulmagid, 2008). The study in New Wadi Halfa Agricultural scheme in eastern Sudan, also revealed that Mesquite spread had created on-farm problems in spite of the various benefits provided (Mai, 2008). Regardless of these negative impacts, mesquite as a leguminous plant increases soil fertility, needs irrigation once or twice when firstly planted, grows rapidly, does not invade rainfed irrigated areas with heavy dry clayey soil and also incapable to spread into sandy soil areas. Mesquite has delicious fruits attracting animals and children, have grazing and nutritional values for its sugar content, protein and salt minerals and in Mexico it is the main source for livestock and wild animals (Brunel, 2009). In Yemen, every km of mesquite belt gives 10 to 25 cubic meters of wood income per year and provides fodder for fifty head of sheep and goats (Bazra, 1983). In Tendelity area, western Sudan, mesquite had reduced wind velocity by 14.4% and water loss due to evaporation by 22%, improving soli texture and an increase by 75% of clayey soil contents and ratio of soil organic matter to 3500 kg and total increase in Nitrogen by 11% (El Fadl, 1997). In Karma and

Zaidab basins in northern Sudan, mesquite had improved agricultural environment and increased cotton productivity (Abdelmagid, 2000).

The purpose of this research is to examine some anthropogenic factors exacerbating high siltation rates and mesquite expansion which have led to decline of cultivable agricultural land and main crops production in Toker Delat in the context of resource management. For achieving that, the paper reviews the study area by explaining good geographic location, hydrology of the Baraka River to verify that there is adequate water for irrigation, exploring high siltation rates, the introduction of mesquite and reviewing declining of agricultural production and productivity of the major crops. The paper then proceeds to research methodology by reviewing satellite images to give clear picture about mesquite expansion. To link between these natural resource and management context, the section on results and discussion has concerned with that. Based on the research findings and the geography of the study area, some suggestions to help alleviate these two problems were proposed by the author.

The study area:

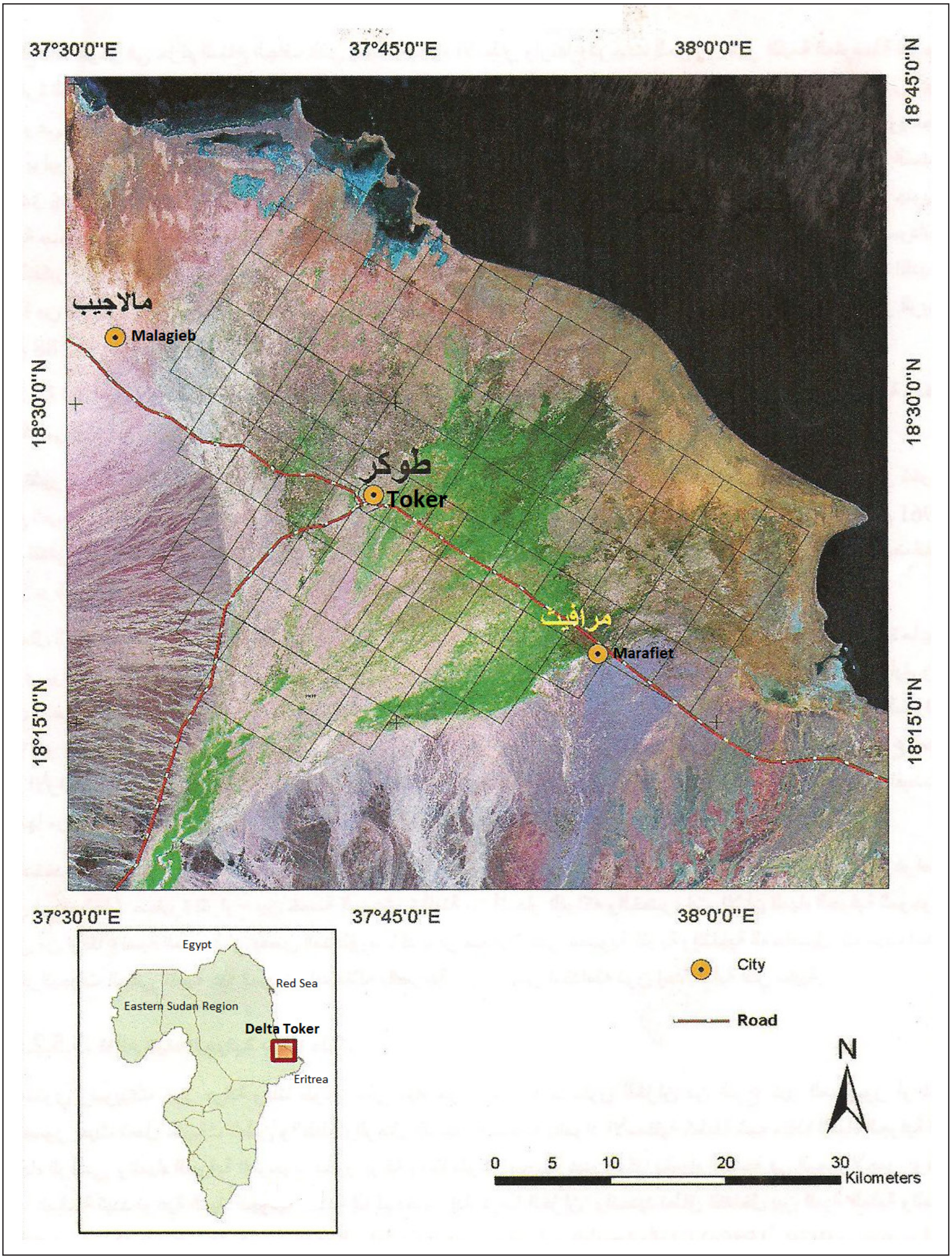
Toker Delat locates between $18^0\ 18^/$ - $18^0\ 40^/$ N and $37^0\ 30^/$ - $37^0\ 55^/$ E, and administratively belongs to the Red Sea state which is one of the eastern Sudan region's states (Fig.1). Toker Delat locates close to the main sea ports of Trinkitat by 22 km, Suakin by 90 km and Port Sudan by 160 km (Wikipedia, 2011). The scheme was founded by the Turkish Governor Mumtaz Basha, 1871-1872, who was the first to introduce cotton in Sudan. The scheme was halted during Mahadist rule, 1885 – 1898, and by 1900 the British cultivated 200 feddans by cotton (ACSAD, 2005). Toker – Trinkitat light rail way was built in 1921-22 to transport cotton to the coast for export (Daly, 2002). In 1952 Toker Delat was very famous by organic cotton production when the major client was the British Lancashire Textile Factories.

Barak River flows seasonally with over 640 km length and 55 km width (Wikipedia, 2011). It originates in Ethiopia at 15^0 N and bifurcates in

Eritrea into Baraka and Ansaba. When enters Sudan, it joins with Khor Langaib and the channel becomes wider with slope of 1.5:1000. In south east Toker by 33 km, it enters a narrow gorge and passes through Shiddin cataract where its slope reduces to 1:1000. When it enters the coastal plain, it bifurcates into three branches watering east, central and western parts of Toker Delat. This Delta has an equal axis triangle shape; the base line is parallel to the Red Sea coast while the other two axes are 45 km length (Fig.1). It has an area of 1624 km^2 and average slope of 86 cm/km (ACSAD, 2005).

Baraka River comes splashing with high suspended sediment load ranging from 250 to 980 Million M^3 of silt (Office Files, Scheme Headquarters 2011). It carries 10.6% of its water as suspended sediment load. This amount of silt equals fourfold the annually deposited amount of silt brought by the River Nile and exceeds Gash's River, which is another torrential river in eastern Sudan by 1: 10^5 (Alredaisy, 2011). These huge amounts of silt accumulate in different areas of the Delta according to flood discharge. They are deposited into new strata added to the soil, differing in thickness by place and time of the year. It is annually flooded and more than 406,000 feddans (1 feddan = 4200 m^2) are inundated by flood water. Flood starts in mid July up to September in duration of 40 to 70 days. It is violent and strong with flood interval ranging from few hours to several days. Water discharge might reach 1200 m^2/s. The annual average discharge of Baraka River is 400 million m^3 and annual amount of water ranges between 205 and 980 million m^3 (ACSAD,2005). The highest estimated discharge is 800 million m^3, the moderate is 500 million M^3 and the lowest is 200 million M^3 of water. The coefficient of surface runoff is 0.012 (ACSAD, 2005). Nearly 60% of this amount of water is discharged into the Red Sea (ACSAD, 2005).

Fig. 1: Location of the study area in eastern Sudan



Source: ACSAD (2005)

The aquifer of the Delta is composed of alluvial sediments including a zone composed of dry sediments of silt and sand, underlain by a zone of freshwater aquifer with a thickness of 10 to 80 m and a surface area of 200 km^2 (El Gaily, 2007). This is underlain by a transition zone of brackish water bearing layers and a thickness of a few meters to tens of meters. This zone is underlain by a zone reflecting saline water-bearing formations or possibly clayey layers with an average thickness of 15 m. The annual groundwater discharge is 32 million m^3 (El Gaily, 2007).. It is recharged annually by 31 million m^3 from the flood water of River Baraka. Groundwater in storage is estimated as 600 million m^3. The average yield of the boreholes is estimated to be 40 m^3/h, but the dug well yield is low (5 to 10 m^3/h) (El Gaily, 2007). Depth of artesian wells ranges between 10 and 20 meters with average pumping of 15-25m^3/hour (Toker Delat Agricultural Scheme, Irrigation Section Files, 2011).

Mesquite was firstly introduced in the scheme in 1962 by Forestry Authority to stop wind erosion that particularly caused by ‘’ Ahataib’’ winds and to stabilize sand dunes and to reduce dust. Its growth was promising to encourage further plantation for sand dunes stabilization. In addition to those benefits, mesquite became a source of income for charcoal traders and food source for animals. Mesquite is found to be spreading through camels and goats excreta. The two types of Schlensh and P. juliflora mesquite dominate the Delta (Abdulmagid, 2008). They are highly resistant to harsh environmental conditions, denser and reproductive twice a year and highly competent with natural fauna. Their height range between 4 to 7 meters and stem thickness ranges 12 to 20 cm with 600 trees per feddan (Asim, 2007). By 2011 mesquite occupied 76% of the total area of the eastern Delta and 48% of the central Delta area. The western delta has been abandoned because it was occupied by densely Adlib trees and sand dunes which are obstructing flood water. Mesquite was found to be well adapted to places with high moisture content including drainage lines, irrigation canals, bridge inlets and outlets and irrigated farm lands but has been less successful on land where native vegetation is still vigorous. Areas suffer most from mesquite expansion in Toker Delat is characterized also by light soil susceptible to water and wind erosion, bare land without agricultural or forestry use, having reliable humidity for growth, bare land unexploited by agricultural or forestry activities. Mesquite draws fresh aquifer water in addition to huge amount of sea water that is mixed with fresh water, ultimately affecting availability of good quality water for cropping (Abdulmagid, 2008). Mesquite caused loss of fertile agricultural lands and its economic benefits led to conflict became in the local community.

Irrigated area during high discharge reaches 50,578 feddan while in low discharge it reaches 10,115 feddans. Since Baraka River bifurcates into three parts, the British have kept on building the irrigation system to water eastern, central and western parts of the Delta. The eastern delta has an area of 125,000 feddans and was divided into 785 blocks (Office Files, Scheme Headquarters 2011). The central delta, which is the most fertile part that can be cultivated even during moderate floods, has an area of 167,000 feddans and was divided into 1,036 blocks. The western delta has an area of 128,000 feddans and divided into 800 blocks. Division of the delta into these three parts was to slow down heavily splashing flooding and to facilitate equal distribution of flood irrigation in order to avoid higher siltation in one part than another. Nowadays, the only irrigated part is the central delta where successive sedimentation has raised the Delta base level.

The total number of farmers is 5000 (Office Files, Scheme Headquarters 2011). The area allocated to a farmer is called “Dhimin” which differs from one farmer to another. Maximum allocated area per farmer does not exceed 500 feddans and is limited to few farmers. Some other farmers who do not own land, share land with owners of “Dhimin” in a type of landholding called “Under Dhimin”. Their number is estimated at 24,000 (Office Files, Scheme Headquarters 2011). They are legally registered by the scheme administration. Some annual changes occur in registered numbers and names of farmers due to inheritance. This type of landholding allows using land when inundated by flood water.

Another type of landholding is called "Tribe's land" which is officially registered under a nominated tribe and collectively owned by that tribe under supervision of the Head of a tribe. If it had been inundated by flood water, it would have been distributed among the members of that tribe conditioned that they do not own a land. Another type of landholding is called "Bayadh land" and belongs to the scheme administration. It is licensed for one season to farmers who do not own land at all. There are, of course, agreements happen between lands owners and some other farmers quitting these official agreements including renting and cultivation by rewarding quarter of the net crop production (called quarter of a poor) or half of production. ''Taken'' land type belongs to the scheme administration which is ''Taken'' from a farmer when he violates the agreement or fails to utilize it or to pay Bank's debts. 85% of the farmers depend on self-finance while 15% of them depend on money loans from traders to finance their agricultural activities (Office Files-Scheme Headquarters, 2011)

To protect agricultural lands from high flooding, a front barrier was built in the Delta during the period 1900-1926 (Office Files-Scheme Headquarters, 2011). This barrier had included coastal areas and sand dunes which were habilitated and linked together to prevent flood water to reach the sea and to be used increase into irrigation. Prior to that period, cultivated area did not exceed 50,000 feddans in most of the years, except three years when cultivated area exceeded 120,000 feddans (Office Files, Scheme Headquarters 2011). The general mean of cultivated area during that period was 45,000 feddans. During the period 1927-1976, there was an increase in the mean cultivated area to reach 77,000 feddans due to high flood. The cultivated area had exceeded 150,000 feddans for four times. This phase can be called post terrace establishment during which mesquite had occupied areas characterized by flood water accumulation and fine sediment. Shawatir (rectangular area of 25x30 m) constitutes 25% of the total cultivated area. They are cropped by Dura to protect cotton area from dust storms. But, since the price of cotton has dropped worldwide and there is necessity for food crops, farmers tend to increase Shawatirs area by

50% on the expense of cotton area (Office Files, Scheme Headquarters 2011).

Cost of production in Toker Delat is less by 14% compared to other agricultural schemes in the Sudan. This is due to climatic and location characteristics. About 70% of the rain falls down during November to January. Average humidity is 59%, temperature range is 22 – 46 C^0 while average sunshine range is 6 to 8 hours a day (Meteorological Office, Toker, 2011). Remoteness from other agricultural schemes in Sudan has obstructed plant disease transmission. Torrential floods bring high sediment load which increase soil fertility. ''Haboob'' winds blowing from October to December kill insects and vectors to allow for no use of pesticides which is advantageous for organic agricultural products. The hot '' Ahataib'' winds blowing from June to the beginning of August invert soil and reduce soil tillage cost. Wintry rains help complementary irrigation. Annual mean crop productivity in 2011 was 3.7 for cotton, 5.9 for Dura and 2.5 for millet. Farmers exert more efforts into cotton and millet cultivation because they are source of income. There also appears to be significant difference between the two means of productivity of Dura and millet due to that Dura is more consumed by the majority of the population while millet is more consumed by West African tribes. The period 1997 to 2011 had revealed smooth curve for vegetables area, declining cotton area, fluctuating Dura and millet area. Cropped area greatly declined to 62,000 feddans and mesquite became the first competitor on available cultivable land (Office Files, Scheme Headquarters 2011).

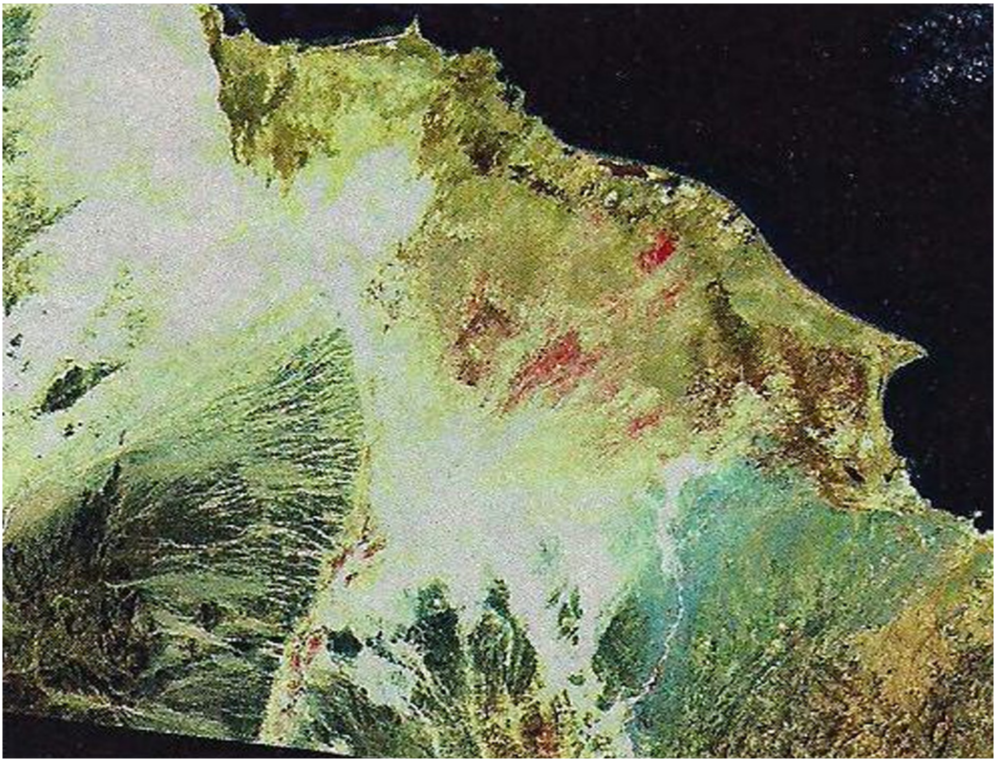
Methods:

The field work was carried out through general discussions with farmers and Head of staff of the scheme during 27-30 March 2011. It is based on research type interviewing methodology with farmers and Head staff of the scheme. The Delta is divided into three sections, eastern, central and western. In each section, two groups of farmers including 10 to 14 persons were interviewed. They were collected by Heads of farmers whom were firstly contacted to facilitate group discussion. Farmers are chosen according to their accessibility during time of interviewing. General collective discussion with these groups of farmers was focused on basic problems of the scheme in terms of siltation and mesquite expansion. Collective discussion with farmers also had focused to determine the role of the Government and community into exacerbation these two serious problems. Their comments were collected directly to form the base for the fieldwork data of this manuscript. Head of farmers have substantially contributed into the administration of discussion into making language of communication between interviewer and interviewee more accessible and easy to understand. In addition, direct interviewing and discussion with Head staff of the scheme has included the vice manager of the scheme and Head of affiliated department. It is focused on shortcomings of agricultural policies, government financial funding, role of community into mesquite expansion, problems of management. They have also provided the author with relevant office data.

Satellite images have been provided to clarify areal expansion of mesquite in the delta. They have included Landsat MSS for 1976, Landsat TM for 1986 and Landsat ETM for 2000 which were provided by ACSAD (2005). The progress of mesquite into the Delta was detected in the years 1976, 1986 and 2000. This helps to show spatial expansion of mesquite since a span time of ten years between 1976 and 1986 and fourteen years between 1986 and 2000. Satellite image of 1976 shows mesquite appears in red color, while in the satellite images of 1986 and 2000 it appears into green.

Annual rate of mesquite expansion in the Delta is estimated by dividing the total area occupied by the number of years since introduction of mesquite into the scheme in 1962. This gives 49 years time span between 1962 and 2011. The amount of silt deposited annually by River Baraka is estimated for the lower and higher values of sediment load by Baraka River provided by Ministry of Irrigation and ACSAD (2005). Each value was calculated by multiplying the annual amount of transported silt at the specified value by average discharge days which was estimated at 55 days. Data of aquifer characteristics was obtained from El Gaily's study (2007) which is also used to confirm mesquite depletion of the aquifer water. Percentage was calculated for landholding by landholders in the study. Relevant office data was collected from the headquarters of the scheme in Toker town and statistics department of Ministry of Agriculture in Khartoum.

Fig. 2: Toker Delta 1976, beginning of mesquite expansion in red color Landsat MSS.

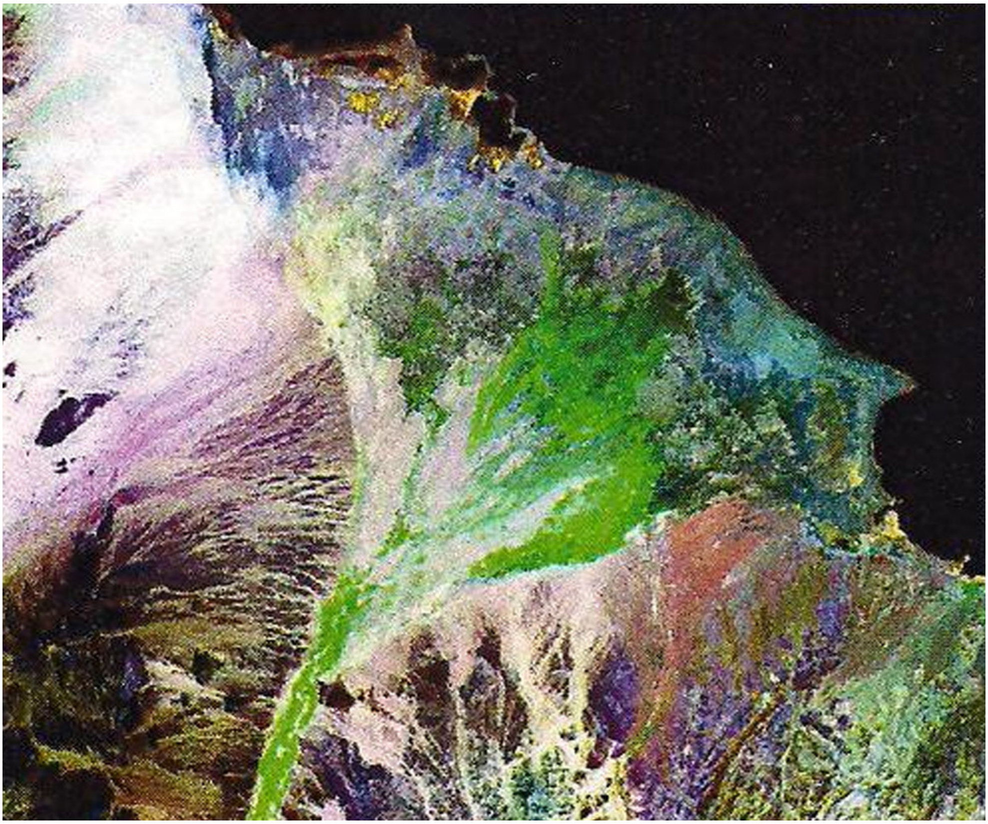


Source: (ACSAD, 2005)

Fig. 3: Toker Delta in 1986, expansion of mesquite in green color. Landsat TM.

Source: (ACSAD, 2005)

Fig. 4: Toker Delta in 2000, occupation by mesquite in green color. Landsat ETM.



Source: (ACSAD, 2005)

The main studies and projects that provided most of the information within the manuscript have included the study by Musa (1987) on water source in Red Sea state. Asim's study (2007) on mesquite impact in Toker Delat has provided information on the nature of this tree and its impacts. Elgaily (2007) has studied the aquifer characteristics of Toker Delat and provided basic information about that for the study here. The Kuwait fund for eastern Sudan in collaboration with the Government of Sudan and international donors and investors conference for development of east Sudan, Kuwait 1-2 Dec. 2010, have also provided good information about potentials, mesquite and high siltation problems in the study area (www.kuwaitfund.org/eastsudanconference. Sudan productive capacity recovery program (SPCRP2010) has studied Toker Delat agricultural scheme and made available good information on mesquite problem and methods of combating its future expansion. The study by Engineer Osman (2010) on the negative impacts of mesquite trees in Toker Delat was also very benefit to discuss the human side into this problem (Osman, 2010). The study on production of vegetable for export in Toker Delat has highlighted the problems of agricultural production as due to mesquite expansion (Sudan economy.com.2010). Rehabilitation of Toker Delat sponsored by Government of Sudan has also highlighted the scheme's problems and strategies for how to overcome them (Sudantribune.com.2010).

Anthropogenic factors exacerbating high Siltation:

The fact here is that high siltation and mesquite expansion in the Delta are highly interrelated. Calculation of annual cumulative siltation by using the lower range value of sediment load (250 Million M^3 of silt x 55 days) gives 24.5 Mm^3 of silt and for the higher value of sediment load gives (980 Million M^3 of silt x 55) gives 20.6 10^6 $Mm^3$of silt. Siltation is more accelerated by the average slope of the Delta which is 86 cm/km. Technical staff of irrigation reported that high silt content by Baraka River impedes the execution of any projects to administrate flood water which will be faced by this huge amount of silt. In addition to that, removal of vegetative cover due to tree logging in Sudan, Ethiopia and Eritrea, according to Head Staff of Forestry Department in the scheme had increased load of transported materials brought by Baraka River. The influence of anthropogenic factors according to farmers is that high siltation is exacerbated due to the collapse of partition built between eastern and western delta which led to the flow of water inside the western delta which has been out of irrigation for 15 years. This is in addition to lack of maintenance of the established terraces organizing distribution of irrigation which is more enhanced by mismanagement of surface water which had led to increased soil erosion to add to the River brought load. Absence of proper irrigation system and methods of water administration allow for water accumulation in valleys and low lands compared to flat areas. The whole amount of transported material accumulate in the central Delta although in the past water was distributed evenly within the three parts of the Delta. This has raised the central Delta base level in situations of absence of maintenance and adequate financing due to privatization of the scheme for more than fifteen years where dependency on self financing for all concerned irrigation matters is depending on shear financial resources of the scheme. This system of flood irrigation needs continuous inspection which depends on trained technical engineers. Farmers did not see irrigation engineers at al due to shortage in staffed technical team. Absence of credited budget to remove additional silt from irrigation channels, lack of machinery, technical staff and referencing to the National Ministry of Agriculture Headquarters in Khartoum, capital of Sudan, delay taking decisions in appropriate time to solve irrigation problems. Maintenance of irrigation network is almost absent causing waterlogging which affects on whole life in the Delta for three months where soil profile remains humid and saturated accompanied by high precipitation which continues for four months being exacerbated by absence of Asphalt road network to facilitate controlling of flood water. Following the quitting of privatization of the scheme had included the annual allocated budget for the scheme by central government within the budget allocated to irrigated schemes in Sudan. In many cases, that budget was transferred to other irrigated schemes or used to solve emergency agricultural problems in big irrigated schemes such as the Gezira scheme in central Sudan which suffers much from high siltation rates. All these situations enhance conditions for the expansion of mesquite.

Anthropogenic factors exacerbating mesquite expansion:

The annual areal expansion of mesquite in the Delta between 1962 and 2011 is estimated at 6,122 feddans. Satellite images showing mesquite expansion in Toker Delat depict that in 1976 (Fig.3), mesquite was restricted to few parts of the Delta. It occupied small patches along the main channel and had discrete distribution in the central parts of the Delta. By 1986 (Fig.4), mesquite had occupied further areas, continuously expanded by taking the triangle form of the Delta. During a decade from 1976 through to 1986, mesquite expanded by a rate equals twice the rate between 1962 and 1976, which spans for 15 years. By the year 2000 (Fig.5), mesquite occupied the main inlet of Baraka River to the Delta and the majority of the area of the central Delta. This led to decline of agricultural land and depletion of surface and aquifer waters. Depletion of aquifer water is due to mesquite root system capability to penetrate down to 50 m and the aquifer nature of the Delta where there is a zone of freshwater aquifer that has a thickness of 10 to 80 m where mesquite roots can easily reach (El-Gaily (2007).

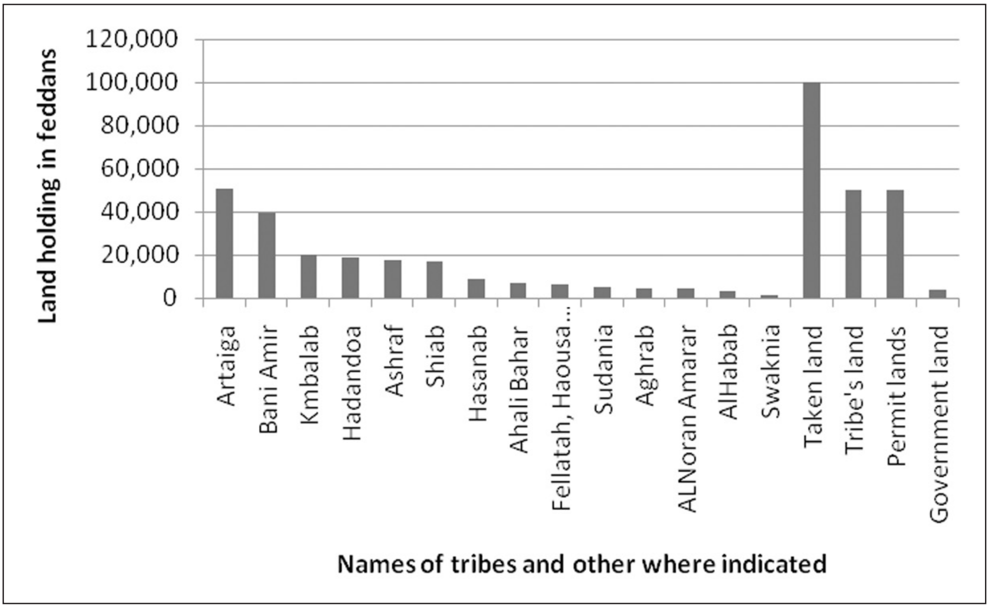
Anthropogenic factors which have contributed into mesquite expansion in the Delta are social, economical and administrative in nature. The conflict between farmers, herders and charcoal traders has contributed into more expansion of mesquite in the Delta due to contradictory and conflicting views by the three economic groups. Farmers view mesquite as invading their land and should be eradicated. Herders and grazers view it as food source for their animals and provide shadow during dry hot season. Charcoal traders view mesquite as source of income. Both herders and traders obstruct programs of mesquite eradication. Farmers know that the coming of herders during the dry season into the scheme to feed their animals on mesquite has participated into its expansion as it spreads through camel excrete and huge areas will be vulnerable to its expansion. Farmers look down to herders as primitive persons and intruders who do not care for others. Similarly, nomad has always looks down upon the farmer because farmers are seen as people tied down to a particular place whereas the nomad has the freedom to move around as part of the search for pasture and water for the animal. These conflicting economically based views, do not meet on to compromise on how to deal with mesquite problem. Continuous conflict will, of course, end into winners and losers. An example of the losers is the population of the village of Marafiet (Fig.1) where the majority has migrated outside the scheme to the nearby Port Sudan town.

Lack of adequate finance to eradicate mesquite is substantial factor. Even the efforts done by foreign Aids were strictly successful because mesquite require continuous eradication otherwise it will reoccupy the areas being cleared. In addition, lacking development programs to invest into mesquite free areas has contributed into its expansion. This is being enhanced by serious lack of water and wind erosion control programs which speed on mesquite expansion in situation of its ability to accommodate with harsh conditions unsuitable for many other plants.

Anthropogenic factors concerned with Landholding and agricultural production relations:

Anthropogenic factors concerned with Landholding and agricultural production relations are closely related with those concerned with high siltation and mesquite expansion. Statistical analysis of landholding data shows different segments of land resource holders in the Delta (Fig. 5). There are lands permitted under a license by authority and constitutes 12.3% of the total land holding. “Tribe’s land” is distributed among Artaiga (12.5%); Bani Amir (9.6%); Kmailab (4.9%); Hadandoa (4.5%) Swaknia (0.3%); Habab (0.7%); Noran Amrar (1%); Shaiab (4.1%) Aghrab (1.1%); Sudania (1.2%); Ahali Bahr (1.7%), Hasanab (2.1%) tribes and Western African tribes including Falatah, Housa and Barno (1.5%) who are mainly migrant agriculturalists. Government’s land constitutes 0.9%. Religious factor into land ownership is seen by agricultural land held by Ashraf (4.2%) who mainly belong to Marghania religious group which used to govern Sudan since Independence in 1956 in collaboration with Mahadi family. Bayadh land constitutes 12.3% while "Taken" land by the scheme authority from a farmer due to his inability to pay debts constitutes 24.6%.

Fig.4: Agricultural landholding by tribes in Toker Delat



Source: Toker Delat Agricultural Scheme Headquarters (2011)

Tribalism dominates land ownership and might retards social cooperation into mesquite eradication. When the tribe's land is left unexploited, in situations not being inundated by flood water, mesquite would eventually reoccupy it. In addition, continuous manual clearing of mesquite is difficult in situation that the majority of the farmers cannot afford with agricultural expenses. In addition, tribe's land as a common ownership, people would not exert much effort to keep on with its clearing of mesquite as they view that any effort exerted would eventually go to the Head of a tribe whom they view as a landlord. Therefore, no common consensus is seen with mesquite eradication campaigns. Farmers also view the Delta land an appropriate for their own and that landholdings by tribes from outside the Delta, particularly those coming from outside, are violation of their own rights. This has negatively affected social soul for cooperation into collective works for mesquite eradications. Moreover, the government's land when left without maintenance and exploitation will give opportunity to mesquite expansion. The government in most situations is incapable to invest, maintain or license such lands to farmers; therefore mesquite will form dense forests. In addition, ''Taken'' land from farmers by the scheme's administration when they fail to pay debt to the agricultural bank or to fulfill with any payments for agricultural services provided by the scheme administration, would be left for a period of time in order to find another farmer. During this period, the land is left without adequate supervision which would provide good opportunity to mesquite expansion. In addition, policy of privatization of the scheme has pushed the scheme administration to work hard to gain money indebted to farmers in order to meet with all agricultural expenses which has created an atmosphere of tension between both sides. Farmers think that local authority does not deserve any support into campaigns of mesquite eradication as it does not support them when they fail their debts. However, methods of irrigation and farming used are lacking proper agricultural technical packages such as seed rate, depth of farming, ways of cultivation, and rates of fertilizers use, grass combat and agricultural insecticides which give chance to mesquite expansion. It is noticed that farmers prefer cultivating certain crop varieties such as White Dura without testing seed vitality. They used to put 6 to 8 seeds in a single hole which is opened by using traditional tools of farming. The result is high plant density which led to high competition on water, nutritive elements which affect on the crop productivity and eventual farmers income. Harmful grasses are eradicated manually and there is complete absence of agricultural extension. The Agricultural Bank does not secure easy financed pasteurized and improved seeds to be distributed among farmers. In addition, high cost of agricultural crops marketing, high value added tax, remoteness of markets and lack of transport means are also influential. Increase of middlemen has reduced farmers' profit margin. This being further exacerbated by the absence of rural development programs on agro based industries, fodder production, vegetable production industries to employ people during times when no agriculture is practiced.

Siltation and mesquite invasion are serious problems in Toker Delat agricultural scheme. This refers to many physical and anthropogenic factors. Having the inherited characteristics of mountainous torrential rivers, the Baraka River is fitting the youth stage of erosion theory. High sediment content refers to head erosion in upstream. Torrential rain and continuous dropping in slope between source and delta of the river resulted in that the speed of the current is reduced and the river begins to drop its load of sediment till it reaches the end of the delta. Deforestation occurred in Ethiopia, Eritrea and eastern Sudan, which has an anthropogenic side, causes an increase in the annual mean discharge of River Bearaka. The change in vegetation cover altered the hydrological response and the pressure for changes in land cover continue to increase to make a possibility for expectation of further changes in the hydrological regime of a river (Marcos et al., 2003). Ethiopia's rivers are accelerated by deforestation and inappropriate agricultural practices (World Bank, 2007), however, more general or overview studies agree on the negative impacts deforestation has on flood safety and the positive effects of wise land use and reforestation (Semi, 1989). In assessing the impacts of Himalayan deforestation on the Ganges-Brahmaputra Lowlands, it was found that forests would not have prevented or significantly reduced flooding in the case of an extreme weather event (Hamilton, 1987).

Siltation problem is depleting financial budget of irrigated schemes in Sudan. In the Gezira scheme for example, it is the main reason for declining agricultural production. The argument here is that, when the British introduced this type of irrigation in Sudan it has proved successful and efficiently operating during their stay in Sudan. Following their departure, that type of irrigation system had deteriorated and even collapsed in some schemes although it depends on gravity and slope gradient and never need mechanical support like pumping or digging boreholes. This type of irrigation requires proper management of irrigation water with simple infrastructure for sustainability. Siltation problem is further exacerbated in Toker Delat due to absence of appropriate land preparation services, follow up, maintenance of terraces and financing, presence of many bodies to decide on irrigation, financing, agricultural administration and farmers affairs being further aggravated by economic privatization policies of the country.

The recent Government's policy towards replacement of agriculture by Oil as the main income source for the Sudanese economy had caused reduction into public national expenditure on agricultural sector which consequently aggravated problems of high siltation and mesquite expansion. Public expenditures on agriculture include short-term costs as well as long-term investments. Investment in agriculture and forestry includes government expenditures directed to agricultural infrastructure, research and development and education and training. To escape these responsibilities, the National Salvation Economic Program in 1993, as State's policy, recommended privatization of many Government owned schemes in Sudan including Toker Delat Agricultural Scheme (MFEP, 1993). This policy was based on uplift of financial subsidy in situations of deteriorating agricultural production; marketing and production problems; devaluation of the national currency and political unrest. Government efforts have gone to Oil sector where from 1990 and on, Chinese, Malaysian and Arab Oil Companies have introduced Sudan into Oil era. Although of success in securing hard currency to finance different sectors of the Sudanese economy, the agricultural sector did not witness any progress in infrastructure or advancement of production, marketing systems and the old issue of "Sudan is the breadbasket of the Arab World" no longer exists. Of course, civil wars in south and western Sudan have depleted Oil incomes till the assignment of Nivasha agreement in 2005 and separation of South Sudan in July 2011. However, data on the proportion of all central government expenditures spent on agriculture and forestry are incomplete in Sudan which is similar to many African countries where agricultural expenditures were between 1988 and 1993 ranged 1.5 to 7.9% of total expenditure. As a percentage of expenditures, agricultural expenditures generally declined from 1988 to 1993 in Africa. Since human capital development is a key component of public agricultural investment, Africa had the smallest share of world agricultural research expenditures (5.7 percent) and human resources (5.5 percent) between 1959 and 1980 (Derrick, 1987). As early as 1978, a FAO study identified a lack of investment in education and training in developing countries as an impediment to agricultural growth (Derrick, 1987). In absolute and relative terms, expenditures on education and training by developing countries were less than those of developed countries (Derrick, 1987). Failure of privatization policy of the agricultural sector, as a face of nongovernmental expenditure on the agricultural sector, have returned Toker Delat to the umbrella of financial subsidy which witnessed a weak Nation emerging from wars and not capable to support and to meet expenditure on these schemes.

Huge areas have been removed in arid Sudan for purposes of extension of agriculture which allowed for the expansion of mesquite. In Toker Delat, mesquite have caused declining of cropped area; lack of job opportunities; spread of poverty due to weak income generating activities particularly among women, absence of natural renewal of local trees due to overgrazing, cutting and drought, increase of dust storms and sand creep due to lack of tree plantation and re-plantation as well as problems of food security and malnutrition (Talaat, 2000). This is similar to Rusizi floodplain and delta where invasive plant species also threaten the ecosystem and the livelihoods dependent upon it (IUCN.2010). Introduction of mesquite in Toker Delat reflects improper management of agricultural planning in the country. These agricultural planners supposed to know dangers of newly introduced plants particularly in case of mesquite which is known worldwide to be as water succulent and invasive to natural habitats. Many imported plants in Sudan have been introduced without prior tests to verify positive and negative impacts. Mesquite has created conflict between beneficiaries of natural resources in Delta including farmers, herders and grazers and charcoal traders. This is similar is to the situation among tens of thousands of Burundian and Congolese where mesquite supports their livelihoods although they cultivate, fish, graze cattle and harvest wetland products (IUCN.2010). The inclusion of grazers, particularly camel herders as beneficiaries of mesquite reflects problems of desertification in the study area and Sudan. In the past, camel herders have their own grazing lands and when they come into agricultural schemes was mainly for marketing their products and buying life needs. In recent years, they became competitors with settled farmers in marginal arid and semi arid of Sudan where one of the main causes of military conflict in Darfur refers back to herders who grab land and intrude into farms. Such type of conflict is evident in eastern Sudan (Alredaisy, et al., 2011) and western Sudan (Alredaisy, 2012). The presence of charcoal traders as beneficiaries of mesquite is associated with demand for that product because of unavailability and high price of home gas although there is national policy to replace charcoal by gas to conserve forest. Although mesquite have secured an income for charcoal traders who might be involved into agriculture, but that activity have halted eradication efforts. Presence of three conflicting sectors of population will definitely impede campaigns of mesquite eradication.

Tribal land ownership as a system of landholding has contributed into mesquite expansion into Toker Delat. Common ownership of land does not encourage people to bear responsibility of eradication particularly when needs manual work. Common ownership of land does not allow for equal distribution of agricultural production among members of a tribe in situations when such members will be prejudiced by heads of tribes. Landholding by some migrants from inside and outside Sudan, had led indigenous people of the area to think about an occupation of their land by foreigners as far as they are still considered to be ''closed tribe''. This more exacerbated by military rebellion groups in the region which raised request for equal distribution of wealth and power in Sudan. That request has caused political unrest in eastern Sudan for many decades and ended in 2009 by Asmara agreement between the Government and rebellious movements. The agreement included rehabilitation of agricultural sector in the region including

Toker Delat. The International Kuwaiti Fund for Development has carried out pilot studies and allocated money funds to achieve these objectives. It is expected that land reform, rehabilitation of the irrigation system and eradication of mesquite will ultimately be achieved.

Conclusion:

The main findings of this research are:

1- Only the central part of the Delta is irrigated which is subject to high siltation rates being exacerbated by many anthropogenic factors.

2- Mesquite has occupied 73% of the total area of the Delta with average annual rate of expansion by 6,122 feddans and being exacerbated by many anthropogenic factors.

3- Farmers, grazers and charcoal traders are confronting on mesquite which have seriously affected its expansion and efforts for its eradication.

4- Landholding system, problems of agricultural production relations and marketing have contributed into mesquite expansion.

5- Government policies of privatization, problems of mismanagement and financing have contributed into exacerbating high siltation and mesquite invasion.

Efforts for alleviation of higher siltation rates and mesquite expansion in Toker Delat agricultural scheme should be practical and interrelated. High siltation rates could be alleviated through coherent knowledge of the hydrological behavior of the River Baraka from source to Delta. Data of Baraka River source in Eritrea and Ethiopia are to be available where vast areas are subject to heavy erosion, deforestation and denudation by surface runoff. They are the main source for these high siltation rates. Because the study area is part of the great African rift valley which is characterized by high mountains and fault formations, it might be difficult to utterly control high sediments load carried by such torrential river and to put a concise plan to use its waters appropriately. But, consideration the characteristics of catchment and the basin, and emphasizes on the inherited variations in geomorphic characteristics, rainfall inputs, discharges, it is expected to be highly valuable.

Suggestions for mesquite eradication should include preventing more expansion in the unaffected parts of the Delta, use of mesquite forests into charcoal and honey production and gradual replacement of mesquite by forest cultivation and reforming of landholding system. Mesquite can be eradicated through field studies focusing on topography to know about suitable locations for mesquite growth in order to prohibit future invasion. Direct investment into mesquite eradicated areas is essential in order to avoid mesquite re-invasion and water accumulation to avoid formation of mesquite forests through building of fences and sanctuaries. Technical administration of mesquite forests has proved efficient which considers mesquite as a resource that has to be managed properly. The most important element in this type of administration is to reduce mesquite density so as to achieve ecological and economic balance through manual cutting. National Forestry Authority and Center for Forestry Research have carried out many experiments to control mesquite expansion in Kassala province in eastern Sudan and Soba area in central Sudan through cutting. Cutting of mesquite stems at 25, 50 and 75 cm depth has profoundly affected eradication of mesquite if being burnt or not.

Training of farmers, herders and charcoal traders on efficient methods of mesquite cutting under supervision of technical staff is important. In addition, completion of forests resources survey, collection of relevant data on the climate, dust storms and soil have to be stored in database for establishing tree belts and forests' plants. Rehabilitation of vegetative cover should include efforts of enhancement of natural renewal of forests, organizing grazing and supplying herders and farmers with technical packages concerned with plantation of trees, seeding of seeds in valleys and water accumulation areas, rehabilitation of Toker nursery and encouraging individually owned nurseries and training of charcoal producers on modern methods for charcoal production.

Making benefit from the experiences of northern and Nile states of the Sudan into mesquite eradication through Agricultural Extension was vital due to awareness of farmers. Technical method preventing mesquite flowering such as that used also in preventing sugar cane flowering will help into mesquite eradication. Biological methods could include improvement of local trees, use of some insects that are feeding on mesquite fruits and blossoms such as Mozena obtasa and Cutworm which have proved excellent in USA.

Due to conflict created by mesquite between farmers and other beneficiaries, policy makers have to consider that into eradication of mesquite. Because camels and goats are most effective into mesquite spread there should be an alternative for animal feeding through plantation of local trees in some valleys outside the scheme followed by prohibition of camel grazing inside the scheme. This could be enhanced by the fact that Toker Delat has marginal potential for rainfed agriculture. However, annual flooding provides a source for development of water managed farming system and creates a node for dry season grazing by livestock of pastoralists.

Vast areas can be cultivated by white Dura which is considered one of the very important forage and grain crops. It can be used as fodder, manufacturing of Silage, Sirup and Sorgo Sweet Sorghum. This crop is highly successful in Toker Delat due to suitable prevailing climatic conditions, and availability of environmental requirements for the crop, bearing harsh environmental conditions, has waxy deposits on the leaves' surface and locally called the ''camel''. It is more suitable to produce in clayey and light sandy soils and bearing salinity. The Delta area can be invested into cultivation of a variety of crops such as millet, corn, cotton, sunflower and sesame under conditions of irrigated agriculture due to insufficient rain waters to secure plant water needs. Also. In the Delta many fruit trees can be cultivated such as Banana, mango, Guava, and citrus trees and many vegetable types such as tomato, water melon, beans and cucumbers. But, absence of cultivation of suitable species with the prevailing climatic conditions, improved guaranteed seeds, insects combat, and programs for improvement of agricultural techniques and hybrid programs and development of plant varieties for high productivity and production.

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6

Challenges of rapid urbanization to squatter settlements in Greater Khartoum, the case of Dar El-Salam El-Magharba in East Nile Locality

6

Challenges of rapid urbanization to squatter settlements in Greater Khartoum, the case of Dar El-Salam El-Magharba in East Nile Locality

Squatter settlements are unauthorized owner-occupied self-built mode of housing provision. "The unauthorized owner-occupier developer secures a plot of land (either acquitting illegally, through organized mass invasion or gradually by families or small groups, or informally through de facto tenure agreements with landowners) and then constructs a housing unit without official permission, registration or building code" (Aciolyjr and French, 2012). Colonization has disrupted the traditions of self-reliance and resulted in them being replaced by the notion of government as the provider of services including housing and the development of self-help groups, initially in squatter settlements is the microcosm of this larger process (Haywood, 1986). Later, housing has been viewed as a consumer good which must be given a very low priority in development issues and this view undermined the contribution of the housing sector to economic development (Matovu, 2000).

United Nations estimates suggested that nearly one billion people now live in slums worldwide representing 16/th of the planet's population and is expected to double by 2030 (Beardsley et al., 2008), where one in seven people on the planet are expected to reside in urban informal settlements by 2030 (Corburn et al., 2017) and “If no action is taken, the number of slum dwellers worldwide is projected to rise over the next 30 years to about 2 billion” (Dasgupta et al., 2009). They account for 71.9% of the population in Sub-Saharan Africa (Dasgupta et al., 2009), and comprise some 3070%- of the housing stock in many cities and towns in developing countries, and their scale is attributed to the inadequacies of housing finance systems and land development, along with the pressing demographic growth and mass poverty (Pugh, 2000). They comprised a mix of owners, landlords and tenants (Kumar, 1996)and their communities differ in size, character, age, and level of political and social organization (Beardsley et al., 2008).

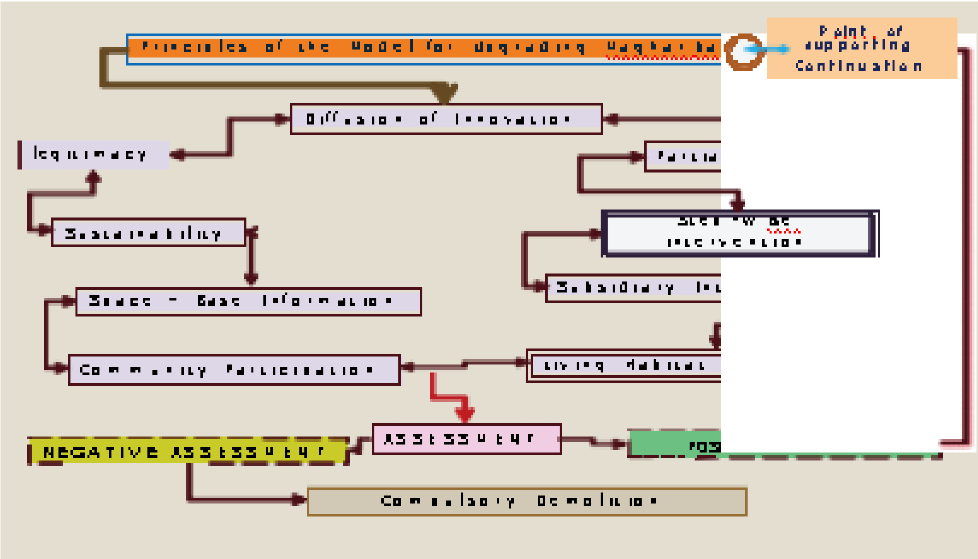
Upgrading is a term given to measure to improve the quality of housing and the provision of housing- related infrastructure and services to settlements that are considered to be slums or that developed illegally. Upgrading has to be understood in the context of cities in low-and middle-income nations where a large and often rapidly growing proportion of the population live in squatter settlements (Sattrethwaite, 2012). Three thematic approaches were identified which are the progressive improvement of physical infrastructure provision; community microplanning and physical transformation through holistic plan (Abbot, 2002). Governments have moved from eradication policies to provision, enabling and participatory policies which was motivated by the recognition that informal settlements were not a problem but a solution to the formal housing markets that cannot fulfill its demand (Khalifa, 2015). The scope of upgrading varies from some minor improvements- for instance some communal water taps, paved roads, and lighting - to comprehensive improvements to the housing and good-quality infrastructure and services, and provision of legal tenure of the land to the occupants. “The consolidation process typically takes many decades after which time these informal are often indistinguishable from neighboring formally developed areas. The consolidation, however, is not a given and it does not always takes place, often the rudimentary settlements remain so, depending on level of community cohesion, investment capacity in housing, tenure security, and owner-occupation" (Aciolyjr and French, 2012). "In terms of wide-scale human welfare and sustainability, the conditions of life in urban squatter settlements have enormous significance. Their scale is attributed to the inadequacy of housing finance systems and land development, along with pressing realities of demographic growth and mass poverty" (Pugh, 2000). Attempts were done to propose models and strategies to upgrade squatter settlements. Ahern, (2013) proposed "Five strategies to build resilience capacity and transdisciplinary collaboration are proposed: biodiversity; urban ecological networks and connectivity; multifunctionality; redundancy and modernization; adaptive design".

The research problem, data sources and methods:

The majority of the squatter settlements in Khartoum state have been upgraded through planning and re- planning, however, they still inheriting their prime problems of growth. These problems were further exacerbated by influences exerted by rapid urban growth around their neighborhoods and internal transformations such as division of houses, transforming to storey-type buildings and highland value which consequent in further crowdedness and over- pressure on inadequate available public services. Some squatter settlements became central places within the vast growing modern residential neighborhoods where the executed afore- planning and re-planning became uncompetitive in regard to rapid changes in the urban milieu. These have created serious challenges to these squatter settlements and to their geographic neighborhoods which could be exemplified by Dar Elsalam El- Magarba squatter settlement. Sources of data included; field visits during January and February 2020 where DarElsalam El-Magarba was divided into four geographic sections, in each section five head persons were selected conditionally lived for more than two decades there, and practiced some community services, and are able to highlight challenges facing Dar Elsalam El- Magarba due to rapid urban growth in East Nile locality. This was further supported by direct observation and firsthand experience of the author's living there for more than a decade, beside data collected from local authority files. Arc map 10.5 was used to produce detailed maps for location, general morphology, distribution of housing units and roads elongation for Dar Elsalam El- Magarba based on Google maps 2020. GIS analysis also produced general elevation map based on DEM 90 USGS.

A model of intervention was built to upgradeDarElsalam El- Magarba squatter settlements (Figure1) including five consecutive principles and five consecutive steps. It was named as "DLSSLSSPA", after the abbreviation of the first letters of its consecutive principles and steps. These principles were Diffusion of Innovation; legitimacy; Sustainability; Space-base information; and Community Participation. The steps were Living habitat improvement; Subsidiary intervention; Step-wise intervention; Partial Demolition; and Assessment of the model on specified time span by field experts and community experience. Assessment could judge for continuation of upgrading (positive assessment) or suggests for compulsory demolition of Dar Elsalam El- Magarba (Negative assessment) and adoption of new practical alternatives.

Figure 1: "DLSSLSSPA: A model for upgrading Dar Elsalam El- Magarba squatter settlement



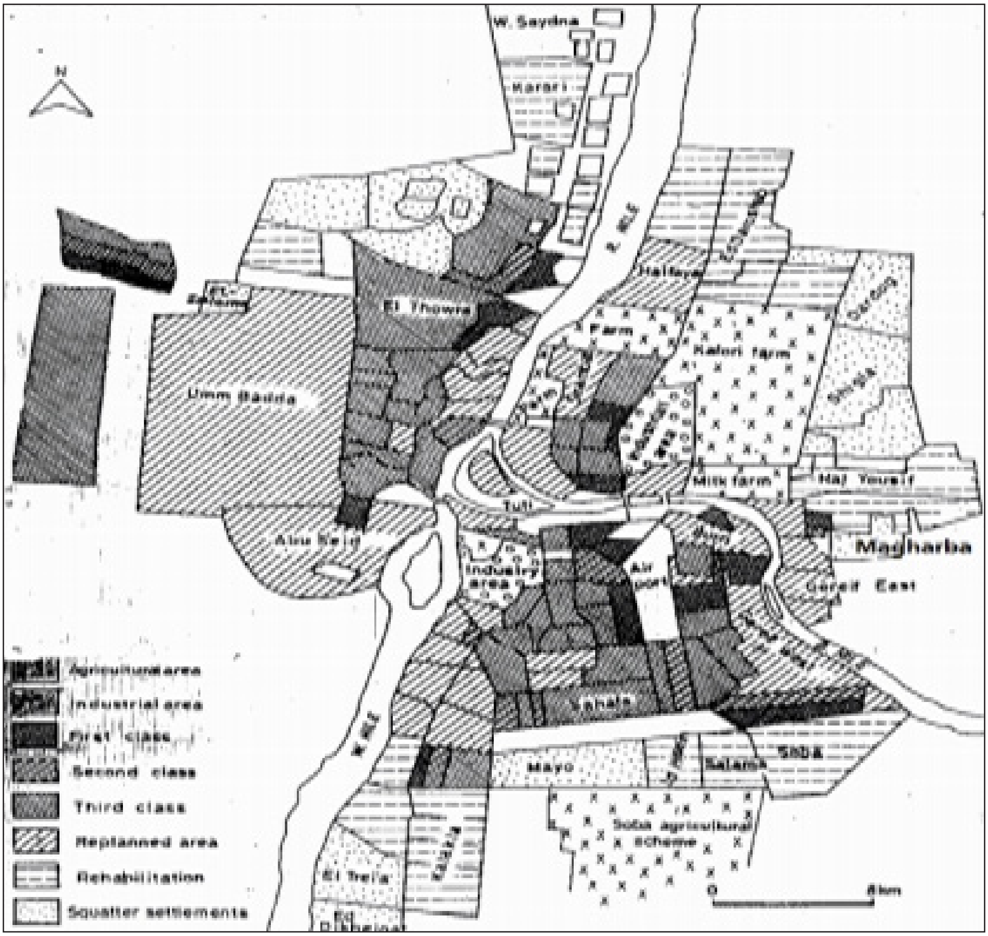
Urban growth and development of squatter settlements in Khartoum state:

Khartoum State'spopulation doubled 140 times during the period 19052000-, and while the number of population doubled by 12 times at the national level it doubled hereby 50 times (El Bushra etal., 2005). The occupied area doubled 250 times during that period (El Bushra etal., 2005), particularly by the begging of 70th of the past century by influxes of migrations where it was "until 1970s dominated pull factors - economic growth, while from 1970s onwards pull factors-drought and conflict with high level of displacement prevailed where the majority of urban poor seeking better livelihoods opportunities, security and services" (Pantulianoetal., 2011). Net migration increased from 0.2 million in 1983 to 0.5 million in 1993, and then to 1.8 million in 2008 (Abdel Ati, 2012), which have over pressed on the already existed high population density of 169/km2 for whole the State (National Council for Population, 2002).

The wide gap between demand and supply, and the unaffordable cost of housing for the vast majority of households in Greater Khartoum have manifested in over-crowding and massive growth of informal settlements. The State in Sudan has opted to replace sites-and-services with core housing as an alternative housing policy because of its perceived economies of scale (Hamid et al., 2014). Over the last two decades, most of the urban population growth in Sudan has been absorbed through a process of residential densification “sub-letting in existing districts” and through “illegal” occupation of sites on the edge of towns (Post, 1994). Over one hundred squatter settlements (Figure 2) have come to form a tight ring around Sudan’s capital cities (El Bushra et al., 1995). Their Types includedinner-city slum areas which are either engulfed or annexed by urban expansion; outer slums which are areas planned by the authorities and distributed to landless; and squatter settlements that built on illegally occupied by newcomers (Eltayeb, 2003).

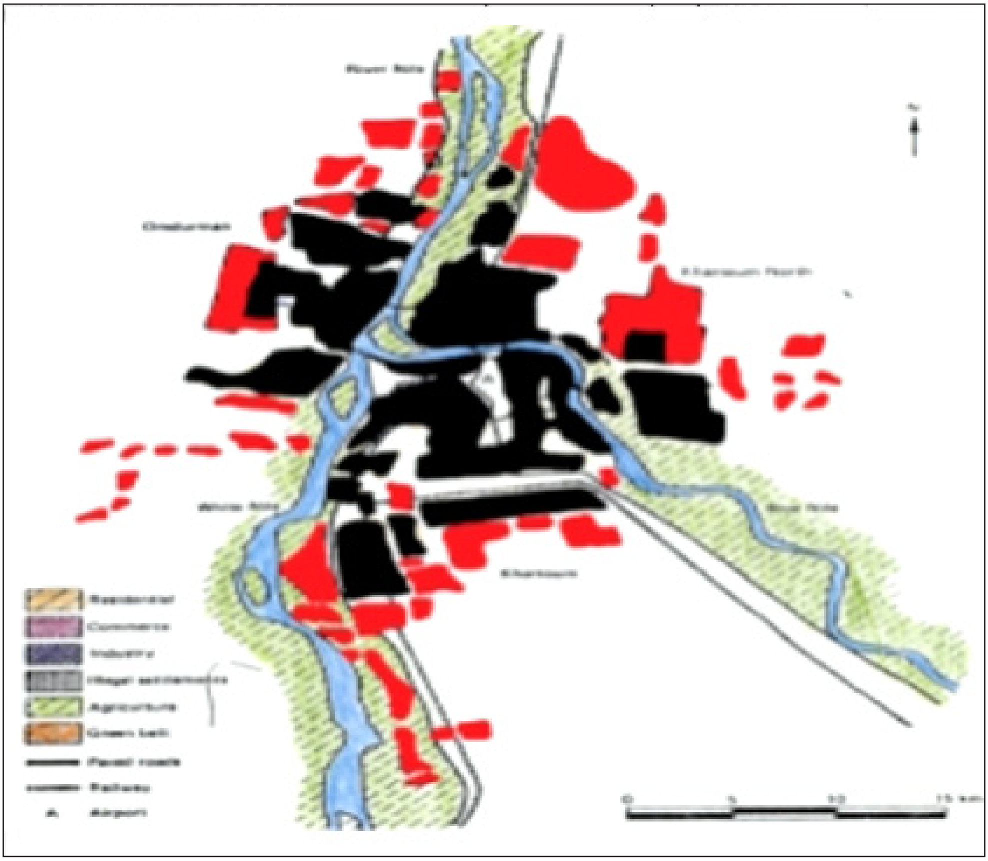
Squatter settlements grew rapidly where by 1983 they made up 17% of the total urban area, and increased to 40% in 1985 (Figure 3) and then to 60% in 1990, while it dropped to 20% by the year 2000 (Figure 4). That was because of interventions by demolition, planning, re-planning, and transfer of some squatters to newly planned residential blocks such as Dar el Salam. The major consequences could be that “poor people being moved off prime value land, dramatic rise in value of real estate and cost of living, unskilled labor-growing numbers and competition from neighboring countries” (Pantulianoetal., 2011).

Figure 2: Khartoum State residential areas and slums



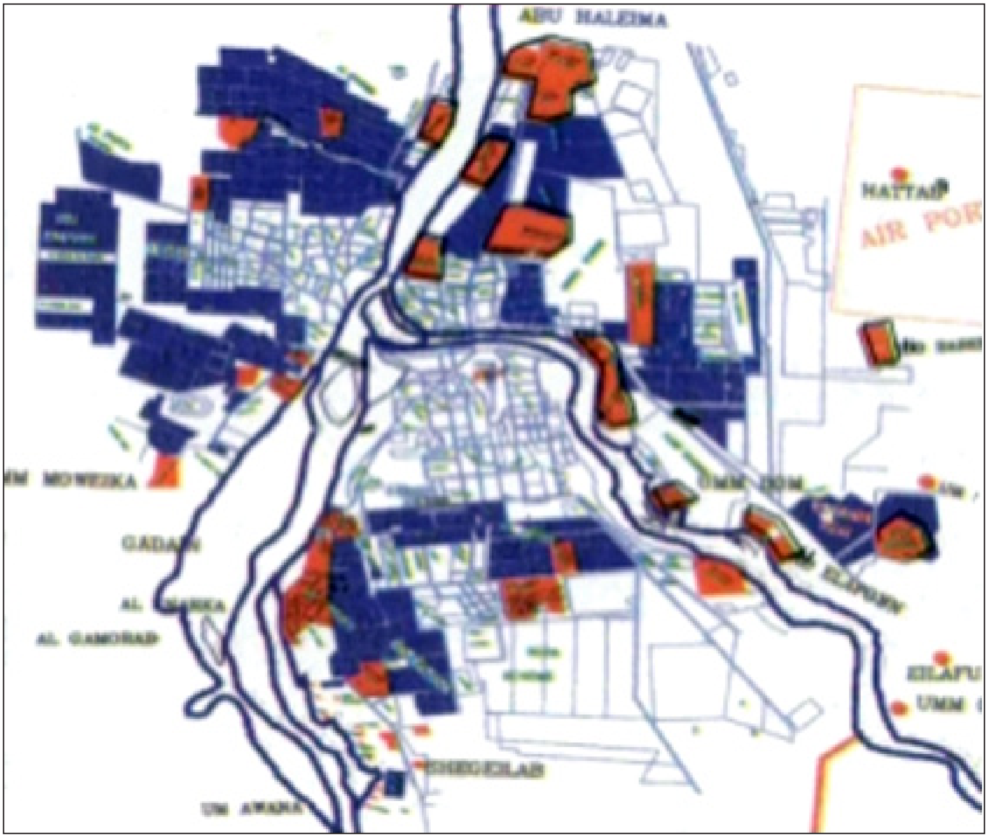
Source: Ahmed A M.1989.

Figure 3: Squatter settlements in 1985 (40%)



Source: Ministry of urban planning, Khartoum state, 2000

Figure 4: Squatter settlements in 2000 (20%)



Source: Ministry of urban planning, Khartoum state, 2000

Growth, development, and planning of Dar Elsalam El- Magarba:

Dar Elsalam El- Magarba squatter settlement (Figure 5) started as a small village in Khartoum North, named after El- Magarba tribe which settled on declared land recognition by Batahien tribe in late 19th century. By mid 1970th it grew rapidly through de facto of land tenure agreement with landowners on behalf of being their ancestors' ownership. This spatial growth was part of an increase in occupied area in Khartoum north which increased from 6.3 km2 in 1970 to 46.5 km2 in 1980; and then to 204.9 km2 in 1998 (Survey Department, 1998, and Engineering Affairs, 1999).

Rapid spatial expansion of DarElsalam El- Magarba made official intervention a necessity where in situ planning was imposed conforming to official attitudes of planning in Sudan since 1956 which have range from extensive demolition to selective demolition and resettlement and some upgrading (Ahmed, 1989). Official intervention in DarElsalam El- Magarba during 19931994- produced a grid of narrow roads and corridors (Figure 6) discordant with rain water natural discharge and collection of household disposals and wastes; house plot area of 200 m2 minimally and 600m2 maximally, increase of built area to accommodate more population, division of Dar Elsalam El- Magarba into eight blocks; provisioning of piped water and electricity services. It also produced very few open spaces for community services which shortly, obliged them to use open spaces in neighboring residential areas to build basic schools for their children.

Figure 5: location of Dar Elsalam El- Magarba squatter settlement

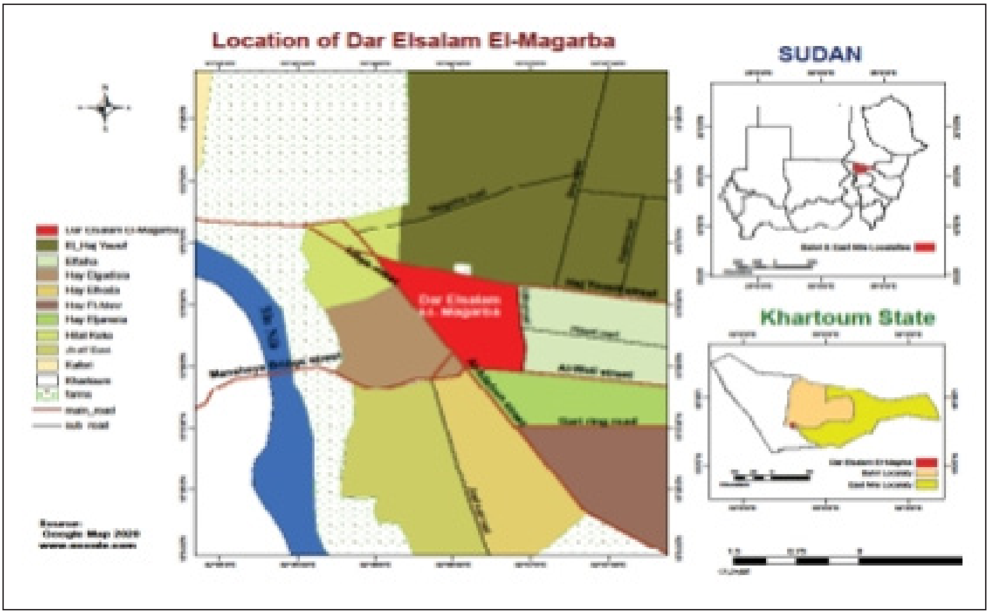
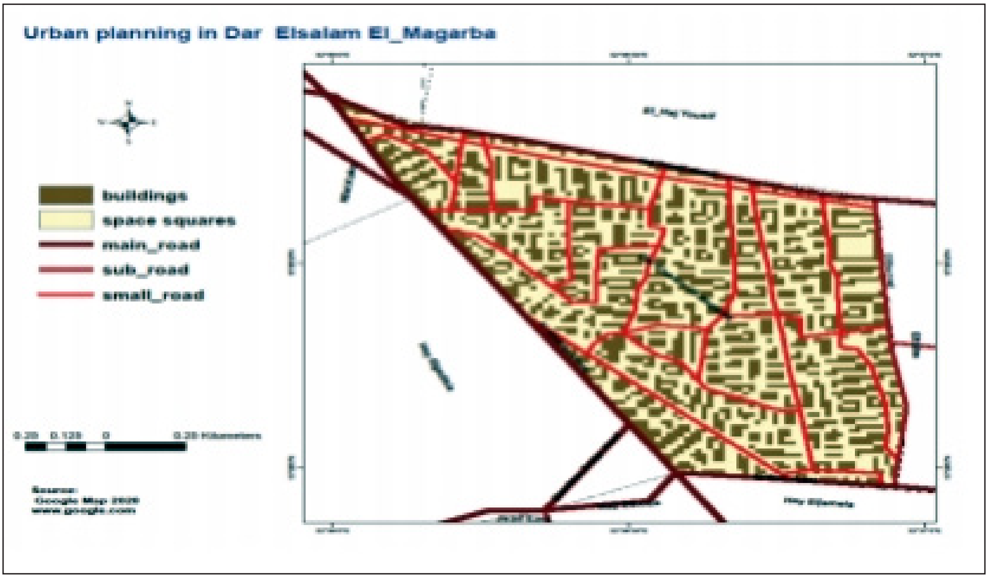


Figure 6: Morphology of Dar Elsalam El- Magarba produced by planning intervention



Source: GIS analysis based on Google maps 2020

Intervention for Dar Elsalam El- Magarba planning also, produced two main narrow unpaved roads, one extending northeast-southwest with a length of 1042 meters and a second one extending north-south with a length of 748 meters (Table 1), meeting together in small traditional market in the middle of Magharba. The northern limit of Dar Elsalam El- Magarba is delineated by Haj Yusuf Street extending for 1750 meters; Wali Street from the south with 680 meters extension; Elfaiha street with extension of 1000 meters in the east; and Al-Ailafoun Highway extending for 1714 meters in the west (Table 1). A geometrical shape of Dar Elsalam El- Magarba over as estimated area of 1,500,000 square meters was ultimately produced, neighbored by Graif east from southwest, “Faiha” from the south and the east; Haj Yusuf from the north; andElgadiesia from the west (Figures 5 and 6).

Tabe 1: Road characteristics within Dar Elsalam El- Magarbaand its outer skitrs

Name	surface	Shape length	Road length	Type
Magharba-Mid. Street	unpaved	0.006967	748	No mid-island
Dar Elsalam El- MagarbaStreet	unpaved	0.009436	1042	No mid island
Al Wali Street	Asphalt	0.006339	680	Two-ways
Haj Yusuf Street (Kassala Street)	Asphalt	0.016292	1750	Two ways
Kaddafi Highway	Asphalt	0.015639	1714	Two-ways

Source: GIS analysis based on Google maps 2020

East Nile locality witnessed empirical residential development during the period 2005- 2019, following the opening of Munshia Bridge in 2005 that linked Khartoum town with east Nile locality. The eastern part of Khartoum town represents a recent "urban growth pole" in Khartoum town. It is characterized by first class residential areas extending along three main north-south roads meeting with Khartoum-Medani Highway to connect with new first class residential extensions in Soba area. Excessive increase inland rent in Khartoum east drove many peoples to seek for alternatives among which, and preferably due to geographic proximity and affordable land prices and rents, was the east Nile residential areas. They are part of the skeletal plan for development and promotion of Greater Khartoum for the period 19912000- over an area of 8000 hectares for development, where 4700 hectares were allocated to residential areas to enroll growth up to the year 2000 (Banaga, 1994). The plan basically proposed the development of urban centers neighboring the already existing occupied areas to enroll population activities and services provided that being connected by transportation networks. Some residential areas developed rapidly around and close to the Blue Nile such as Huda; Gadisia; "Hai" Gama'a, HaiNasr; and Munshia east, and very recently Blue Nile Hai. Some others developed along the Ring Road connecting Gaily Oil Refinery with Munshia Bridge, and along Al-Ailafoun High Way connecting with Soba Bridge (Figure 5). Older residential areas of Hajj Yusuf and Hilat Kuku were also developed and similarly, remote residential areas of Tilal; Wadi Akhdar "Green Valley", IDD Babiker were also rapidly developed.

This rapid growth of residential areas was accompanied by huge Arab agricultural investment schemes which made of the east Nile locality a "regional growth pole" in Khartoum State.Manymarket areas have developed including Suk Kuku, for example, where its domain extended southwards and eastwards along the main roads passing by Dar Elsalam El- Magarba squatter settlement, to connect with towns of Khartoum and Khartoum north and Omdurman via transportation networks, and similarly did Suq Sitta (six) which connected remote residential areas of the locality with central places in the locality and other parts of Khartoum state (Alredaisy, 2011). Along the Ring Road and Al-Ailafoun Highway many residential areas were developed (Figure 7) and similarly, many service centers including central markets (Figure 8); car maintenance works; private clinics, banks branches, oil service stations, schools; and some University colleges.

Figure 7: Modern residential growth in east Nile Locality (Hai El-Nasr) Photo credit: SamirAlredaisy (December 2019)

Figure 8: East Nile New Central market
Photo credit: SamirAlredaisy (December 2019)

Consequences of recent urbanization on Dar Elsalam El- Magarba squatter settlement:

The results of rapid urbanization in east Nile locality on Dar Elsalam El- Magarba could

be outlined in the following facets:

– **Architectural disconformities:** Some houses on the outer skirts of Dar Elsalam El- Magarba were transformed to modern multi-storey type and became alike to the surrounding first class residential areas or neighboring formally developed areas (Figure 9), however; many houses are still keeping their primary design and traditional building material (Figure 10). This further caused landscape distortion and disconformity with surrounding first class residential areas (occupancy distortion).

- **Change of the outskirts functionality:** Outer skirts were utilized by businesses works such as car service, private schools, clinics, oil stations, and maintenance workshops, retail trade shops which inevitably increased land rent and some population translocation.

- **Proximity influences: Many:** traditional houses inside Dar Elsalam El- Magarba were transformed to multi-storey types due to changes on its outer skirts and tendency towards architectural similarity with its neighboring first class residential areas. This led to upgrade of many house standards by modern architectural designs and sewerage system, beside rise of land rent by sale to well-off people which caused in the departure of some poor people such as Nubba group to depart to some remote areas in east Nile locality, socioeconomic difference among residents, excess division of the occupied area to accommodate renting demand or to enroll own families, and expectedly the rise of population density, crowdedness; and over pressure on lacked behind services.

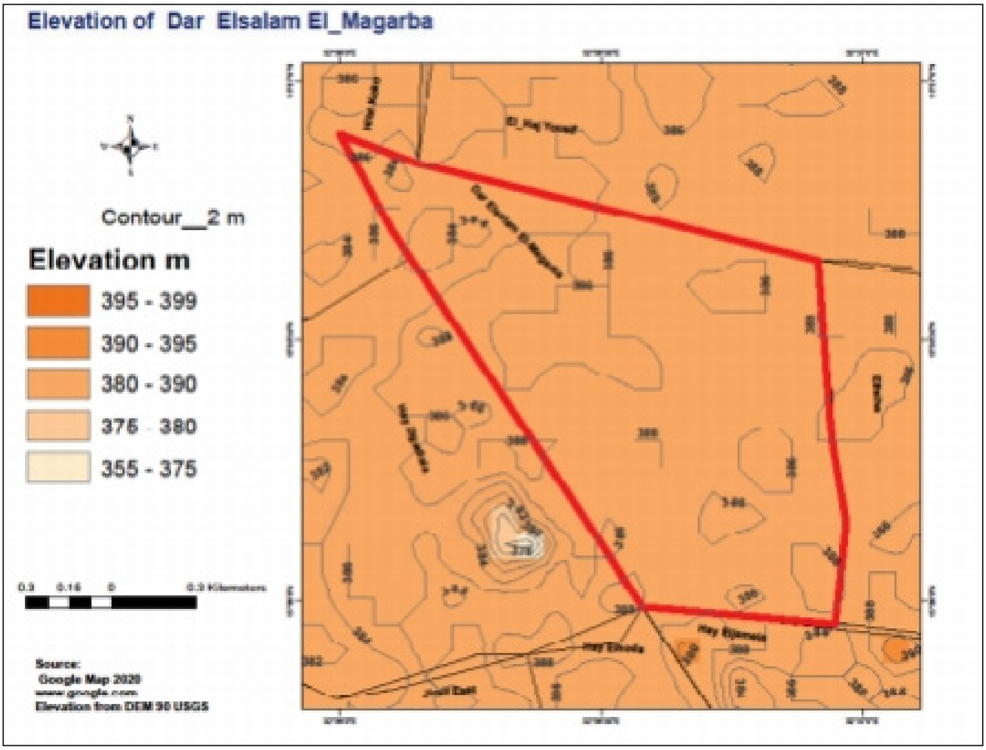
- Location Centrality: Dar Elsalam El- Magarba became a divergence and a convergence focal point of transportation routes as it locates at the mouth of Munshia - Bridge and at the southern inlet-outlet of Suq Kuku (the central market in East Nile locality), close to major public facilities such as East Nile Hospital, Judiciary and Land Registration Complex, and the new East Nile Central Market.

- Traffic obstruction and congestion: Dar Elsalam El- Magarba's mal-plannin imcomplete

Figure 9: Two opposite faces of Elgadissia first class residential area (left) and Dar Elsalam El- Magarba squatter settlement(right) Photo credit: SamirAlredaisy (December 2019)

Figure 10: Contradictory types of buildings: multi-storey and traditional inside Dar Elsalam El- Magarba squatter settlement Photo credit: SamirAlredaisy (December 2019)

Figure 11: Elevation of Dar Elsalam El- Magarba and its neighborhood
Source: GIS analysis of Google maps 2020



Discussion:

The long sequence of urban growth and urban development process in the changing world of Greater Khartoum has consequent on challenges to the inherited squatter settlements such as Dar Elsalam El- Magarba. This sequence is capable to cause urban hazard that could hurt the environment of these human habitats. This is particularly effective since urban planning in Sudan failed to deal adequately with the problems of rapid urbanization due to poor performance relating to developments in the planning environment (Post, 1996), however, it attempted to elucidate the overall political climate, increase popular participation, and decentralizing of efforts (Post, 1996).

In addition to urban hazard, rapid urbanization in East Nile locality had resulted in spatial polarization of its various settlements which increased inequality between them and effected exchanges in their relative positions. Dar Elsalam El- Magarba was subject to that and furthermore, was subject to urban polarity thatcould lead to social structure changing; urban social divisions and inequalities; and intensifying socio-spatial divisions. This was observed within the contrasting urban mosaic of Dar Elsalam El- Magarba's vicinity. According to (Sniretal, 2018), each of these contribution factors can be associated with a typical spatial pattern, and these factors can reinforce each other in specific spatial locations.

Urban hazard, spatial polarization, and urban polarity could be conceptualized within the risk of residential vulnerability framework within which the urban residential system of the East Nile locality became subject to the big influences of the dangers of rapid urbanization in Khartoum state. That rapid urbanization was determined by the overall socio-economic characteristics of the Sudan. They are including political instability and widespread of rural and urban poverty; as well as environmental characteristics of onsets of drought and desertification; and the recurring incidences of population displacement. This residential vulnerability was further fueled in Dar Elsalam El- Magarbaby geographical shift from traditional type of housing to modern one, inside Dar Elsalam El- Magarba and the old residential areas surrounding it, particularly Haj Yusuf from the northward side. Rapid growth accompanied with architectural modernity in the geographic vicinity of DarElsalam El- Magarba was essential to impose that residential vulnerability, but being enhanced by some other vital factors that could be framed within diffusion sprawl, communications and capital investment generated by geographical transaction and contact with rapid urban growth of eastern Khartoum town. This was evidently seen by huge sale of houses in some old residential areas, such as Burri residential area, and movement to the new residential areas in East Nile locality. These residential areas were part of the skeletal plan for development and promotion of Greater Khartoum for the period 1991- 2000. It targeted the doubling of residential area fifth times compared to what was there in 1990, and included in East Nile locality areas such as Om Duban (ELAilafoun small town), Abu Deilaig (central village) and Geili (industrial area) which are lying on the outer ring relative to the old residential mass and connecting them together by circular roads such as the ring road (Figure 5) and Nile bridges such as Munshia- Bridge. It also targeted to get rid of centrality of trade works via the division of Greater Khartoum into central areas, such as the central market in East Nile locality (Figure 8); beside encouragement of vertical growth and improvement of services of residential areas and that of squatter settlements (Banaga, 1994). Collective rapid urban growth and development in East Nile locality has resulted in somehow, a sort of regional polarity with socio-economic power and important capabilities within the geographic region of Greater Khartoum. This regional polarity resulted in settlement divergence and population translocation by land sales; occupancy distortion due to Incomplete human settlements managements in a sustainable way (Elnaziretal., 2004),and particularly to improve the public services and the legitimacy of property and occupancy rights (Pugh, 2000). Furthermore, informal settlement upgrading is widely recognized for enhancing shelter and promoting economic development and can address multiple environmental determinants of health and is a key strategy to promote health, equitable development and reduce climate change vulnerabilities" (Corburnet al., 2017) and would lead to a more sustainable and cost- effective urban development" (Okpala, 1999). The benefits are simply that "people obtain an improved, healthy and secure living environment without being displaced. The investments they have made to their properties remain and are enhanced-this is significantly better than removing them to costlier alternatives that are less acceptable to them. Experience has shown that informal areas upgrading projects are associated with social and economic benefits that are particularly high" (EL Menshawyet al., 2011). "Upgrading also makes a positive impact in reforming governance institutions and in particular, policy reform and changes to the regulatory frameworks that set the legal parameters for upgrading" (Horen, 2004),in addition to introduction of green spaces which have a beneficial health effect (Lee et al., 2011) and their roles in alleviating the adverse effects of urbanization in European cities have been confirmed (Ridder etal., 2004). Our proposed model was named "DLSSLSSPA" as abbreviation of the first letters of its consecutive principles and steps (Figure 1). It is extremely eternal for the future of DarElsalam El- Magarba and the whole geographic neighborhood of east Nile locality to commensurate with ''the skeletal plan for development and promotion of Greater Khartoum for the period 19912000- which was basically proposed the development of urban centers neighboring the already existing occupied areas to enroll population activities and provide work chances and services provided that being connected by transport networks''. Itwas based on the following principles and steps:

1. Diffusion of innovation: Objects to make the community ready to cooperate and influence on overcoming complexity of upgrading process. It could be through diffusion of concepts targeting to treat Dar Elsalam El- Magarba as a residential area needs to cope with new world's changes in human habitats. Diffusion should avoid conventional method-based approaches which are applicable to new areas or sites and instead should focus on applicable principles and best practices.

2. Legitimacy: Seeks to transform Dar Elsalam El- Magarba squatter settlements into a formal neighborhood. This endeavor could benefit, for example, from Favela Bairro slum upgrading program (FBP) in Rio, Brazil. That program was based on slum upgrading without full land tenure legalization and for its use of state of exception, primarily the concession of right to use but not full ownership of land, in order to allow this program to take place (Handzic, 2009). Long term impact and sustainability of upgrading interventions of squatter settlements is limited and consolidating is beginning to provide residents with access to land tenure and services. Recognizing title and security of tenure makes a positive contribution to both the economy prospects of the poor, as well as the national economy (EL Menshawyet al., 2011).

3. Sustainability: Dar Elsalam El- Magarba could be framed within the trend that external interventions have the ability to deal with the key issue of vulnerability and to fight for the need to plan for the long-term sustainability of informal settlements (Abbot, 2002).

4. Space - base information: Necessary space-based information forDar Elsalam El- Magarba upgrading could be provided by conceiving of landscape as the primary problem due to mal-planning and relating ill health conditions, and as the main opportunity for intervention and improvement (Beardsley et al., 2008).

5. Community participation: Communityparticipation is integral part of this model. Some experiences will benefit such as that of Mumbai with slum redevelopment programs. This is because "in spite of the intolerable environmental conditions in which they live, squatters have up to now shown a surprisingly high degree of popular initiative and cohesion, newcomers are pioneers, acquire attitudes and skills much different from those existing in rural areas of their origin, but their motivation and behavioral patterns often change" (Madova, 1976).It suggested for a community among slum dwellers for redevelopment. Also, policymakers and analysts, apart from focusing on tenure status, should pay attention to the existing physical conditions within Dar Elsalam El- Magarba including its location, land use, layout, and the size of the lots within it. They can impact the success of upgrading strategies by considering the preference of beneficiaries for different strategies (Mukhija, 2001).

6. Living habitat improvement: Implementation of physical improvements via a full package of basic services is absolutely crucial to improve the living conditions in Magharba. This is important since interventions in the built form through the provision of infrastructure have been proposed as a strategy to improve economic, social and health outcomes to informal settlements (Beardsley et al., 2008). It is also important to link upgrading and service provision as twin approaches to development of Magharba.

This will make it situated within a particular development paradigm and within community support upgrading initiatives. Dar Elsalam El- Magarba could benefit from the shift of prevailing strategies for addressing non-formal settlements from large-scale clearance and relocation to on-site upgrading and improvement with the goal of integrating low- income communities into their larger urban contexts. This is because many slum areas are big and old and it will be “impractical to think of removing them entirely, to improve them physically without destroy them socially” (Beardsley et al., 2008).

7. Subsidiary intervention: The experience of the National Slum and Squatter Upgrading Program in Thailand (Boonyabancha, 2005) could benefit Dar Elsalam El- Magarba concerning this integral step of upgrading. The program centered on providing infrastructure subsides and housing loans to low-income communities to support upgrading in situ wherever possible and, if not, to develop new homes close by. Support is provided to community organizations and networks formed by the dwellers to allow them to work with city authorities, other local actors and national agencies on city-wide upgrading programs.

8. Step-wise intervention: Adoption of aspects of recent upgrade of informal settlements in South Africa (Brown-Luthango et al., 2017) is important for Dar Elsalam El- Magarba to achieve Step-wise intervention. These aspects included planning, tenure delivery, and public participation within a historical context and within the framework of state’s evolving urbanization policies. “Land use efficiency is an important index to measure the level of land use, from the aspects of society, economy, resources and environment” (Wang et al., 2006).

9. Partial demolition: This will focus on thepossibility of the use of Dar Elsalam El- Magarba occupied residential area to open spaces, provide services and eradicate environmental health problems. The Chinese experience will benefit here since it was confirmed

that this can enroll even aimed to more numbers of residents and open a chance to transfer people from far remote areas to reside here, change thinking of land urban use, reduce cost of living due to long transportational journeys, and control of security. This might require the change of attitudes toward land ownership among urban residents and even the policies of the State towards land allocation through urban residential plans, it might put the society of Dar Elsalam El- Magarba to accept residing in a flat rather than a house and will accommodate with rapid urbanization rates in Sudan. The Turkish model in squatter settlements upgrading (Uzun etal., 2010) might also, benefit Magharba. It firstly, demolished such areas and then legalized them but due to failure incomplete

Assessment of “DLSSLSSPA” model:

The model’s principles and steps should be assessed on specified time-span by official authority and local community and stakeholders to judge for success (Positivity) or failure (Negativity). Positive assessment could lead to continuation of upgrading process which could be fueled via point of supporting continuation indicated in the model (Figure 1). Negative assessment leads to the possibility of exclusion of some principles of the model and/ or inclusion of some new principles which might include compulsory demolition (Figure 1),because slum redevelopment strategies could involve demolition of squatter settlements and redevelopment of new, higher density, medium-rise apartment blocks, including, entirely cross-subsidized housing for the original slum dwellers (Mukhija, 2002).

This proposed model should bear in mind that: “An additional factor to be assessed is the extent to which governments and international agencies have improved income, resources, environment and tenure security in many settlements, but could not eradicate the problems as benefits did not multiply due to lack in institutional development, policy implementation, governance, participation, ignorance of the squatters ’ capability to bring affordable solutions through their own process” (Rahman, 2011). Also, it shouldn’t consider cost and cost recovery as a perquisite to achievement and here can follow the project of large -scale squatter upgrading in Lusaka, Zambia during the 1970s which "Despite the many problems that occurred, especially with regard to cost and cost recovery, the project did have some successes and future considerations" Chawama (Pakodi, 1987).

Conclusions:

This research tried to outline the challenges facing afore planned squatter settlements due to rapid and changing urbanization cadence, where Dar Elsalam El- Magarba squatter settlement in East Nile locality was taken as example. The main results suggest for:

1. Rapid urbanization will continue to make persistent challenges to squatter settlements, either planned or re-planned.
2. Continuous intervention via proper upgrading strategies and coping policies of urban planning is necessary.
3. That our proposed model "DLSSLSSPA" could be benefit to apply in similar situations in Greater Khartoum, and elsewhere.

Proper development plans to stop rural-urban migration, State's policies to provide housing to Khartoum State's citizens and harsh measures to stop land violation by new squatters are necessary prerequisites to improve urban environment and squatter settlements upgrading.

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7

Environmental and Poverty Implications With Traditional Tanning in Omdurman

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Environmental and Poverty Implications With Traditional Tanning in Omdurman(*)

Tanning produces leather after treating skins and hides of animals. Leather is more durable and less susceptible to decomposition. Tanning perquisites the skins to be unhaired, degreased, desalted and soaked in water by using biocides and dithercarbonates, over a certain period of days (Wikipedia, 1016). The place where the skins are processed is called a tannery. Tanning provided lodge for sedentary and nomadic people, shoes, women's ornaments, waterskins, bags, harnesses and tack, boats, armour, quivers, and scabbards.

Tanning can be performed with either vegetable or mineral (chemical) methods. Vegetable tannins are used to retan leather to impart certain specific desired properties or could be used alone in producing leather especially at the rural tanning level by the use of plant material (Zywicki et al. 2002). In ancient and even recent history, such type of tanning was considered "odouriferous trade", so foul smells and usually relegated to the outskirts of town. Regardless of that, traditional tanning products are overvalued on plastic products which domain modern

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Co-authored with Tawfieg Awadalla, research student, University of Khartoum, Dept. of Geography life. Chrome tanning ($[Cr(H_2O)_6]_2(SO_4)_3$), On the other hand, is the most common type of tanning in the world, and regarded as the most efficient and effective tanning agent where tanned leathers are characterised by top handling quality, high hydro-thermal stability and excellent user properties (Victoria et al., 2012), which led to speedily growth of international trade in leather and leather products to meet high demand by industrialised countries (UNIDO 2000).

Traditional tanning is an old craft in Sudan. In many urban centers and states both types of tanning are applied, where there are more than 290 traditional tannery (Africa our continent magazine, issue 7 2015,p2), and more than 30 traditional tanning complex (www.tpsudan.gov.sd/index.php/ar/home/show_export/87), producing one million piece of sheep's and goat's tanned skin, and 800 000 piece of cow's, while the estimated annual production goes to 3,000,000 pieces of leather (Africa our continent magazine, issue 7 2015, p 2). The tanned leather comes first in industrial exports, namely to India, Pakistan, and China and contributed, for example, by 35 million USD in 2014 (http://livestock.sudanagri.net/posts/374803).

The structure of the workforce in tanneries of Europe is predominantly characterized by professional technical and production oriented skills (Social and Environmental Report the European leather industry 2012). Here, environmental sustainability of leather production is essentially based on raw materials processed, process efficiency, pollution prevention and control (Social and Environmental Report the European leather industry 2012). In the developing countries, the structure of workforce is different than that in Europe, where traditional tanners are basically of a rural background and have been driven to urban centers by poor living conditions, poverty, decline of the standard of living and critical naturall hazards of drought, flood and famine (Adepoju 1990; Oucho 1998), and manifest deprivation in survival, knowledge, and material well-being (UNDP, 1997).

One consequence of traditional and mineral tanning is environmental pollution; particularly by chrome tanning containing chrome waste in forms of liquid waste, solid tanned waste and sludge (Victoria et al., 2012), and pesticides residues (Ros and Ganter 1998). The distance covered by a deposited metal in the environment, generally, depends on meteorological factors, topography and vegetation (Nriagu 1988). Transport within the terrestrial and water systems is greatly affected by chemical speciation; chemical forms of chromium and their affinity to chemical and photochemical Redox transformations, precipitation/ dissolution and adsorption/desorption process (Kotaś and Stasicka 2000). Cr6+ is known as the most mobile Cr form in soil and water and tends to dominate in these systems. Redox conversion of Cr3+ to Cr6+ can increase Cr dislocation from the soil into the water systems (Schroeder and Lee 1975; Bartlett and Kimble 1976; James and Bartlett 1983). Chromium as inorganic pollutant is a transition metal and exists in several oxidation states (Kotaś and Stasicka 2000), and use of chromium salts during leather tanning is still common in most of the developing world. Differences in chemical properties of trivalent and hexavalent chromium are observed when compared together (Andersen 1998).The polyphenolic structures of condensed tannins rapidly transforms during the tanning process to yet unknown products (Zywicki et al. 2002).

There is growing concentration of poverty in third world cities where their population is projected to reach 4 billion in the year 2025 compared to1.1 billion in 1985 (Samat, 2002). Conventional economic used income or consumption complemented by nutrition, infant mortality, the proportion of household budget spent on food, literacy and school enrolment rates as indicators to define urban poverty (Rachel et al., 1997). On the other hand, specialists working with rural communities of the third world expanded the definition to encompass perceptions of non-material deprivation and social differentiation (Rachel et al., 1997). In the year 2001 more than ¼ the world's urban population is estimated to live in absolute poverty (UN-Habitat, 2001). Poverty and vulnerability are closely intertwined, where vulnerability stems from location and social disadvantage such as lack of power and often manifested as income poverty (Cutter, 1996). Many poor urban dwellers are socially, economically and environmentally more vulnerable than rural dwellers as demographic indicators have sometimes shown that (Sanderson, 2000: 94).

This paper works to study traditional tanning in Omdurman town, depicting its environmental impacts and discussing the outcoming results within the broad content of Sudan, and finally calls for a new system of environment friendly tanning process that could alleviate poverty and environmental problems relating to this economic activity.

The study area:

Omdurman is located at 15^{0} $45^{/}$ and 16^{0} $30^{/}$ N, and 32^{0} $30^{/}$ and 33^{0} $40^{/}$ E. It extends 38 Km. from south to north along the west bank of the River Nile, and 40 Km. from east to west to the margin of the desert. Omdurman developed in a narrow strip along the Nile, centered on the Imam Mahdi Tomb, 1885 - 1898 (Abu Saliem 1970). Administratively, it includes the localities of Omdurman, Umm bedda, and Karary (Figure 1). The geology is Basement Complex with superficial deposits of Nubian sandstone. Wadis (valleys) drain eastwards to the River Nile following the gentle slope of the surface. The climate is semi-desert. Summer season spans from June up to September, with a peak of rain in mid of August. February to January is a winter season where an average of 15.6 C^{0} was recorded between1961to1990 (Department of Meteorology, Khartoum, 1991). Population density varies from 8350 /km^2 in Omdurman locality, 5520/ km^2 in Omdurman south, and 118/km^2 in southern rural Omdurman (Department of Statistics, Khartoum 1993).

Traditional tanning in Omdurman refers back to the foundation of this town by Imam Mahdi in 1885. Hay Dibagha, which lies along the west bank of the River Nile, was the famous place of tanneries in old Omdurman. Hay Dibagha continued to do that job up to the mid of nineteenth of the past century, when officially translocated to the outskirt of old Omdurman. The new location, however, was open and remote, and by time constituted the center of new residential extension and development of new Omdurman. Now, traditional tanneries spread in many of these residential extensions (Figure 2).

Figure 1: Location of the study area within Khartoum's localities

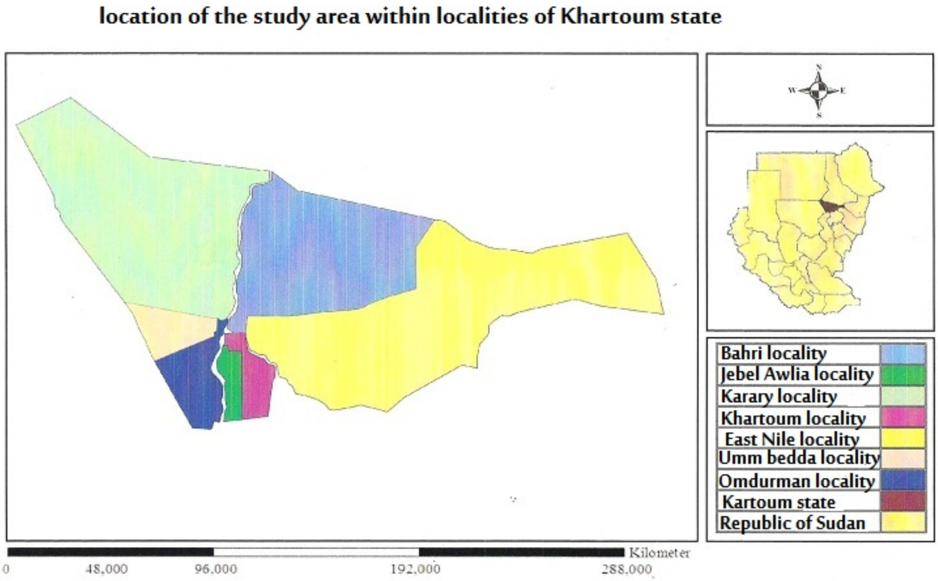


Figure 2: part of the residential area where some of the selected tanneries locate

(Source: Google maps, 2016)

Methodology:

All of the 12 tanneries were included into the fieldwork because their society was small. They were Abuseed block 17, Fitaihab block 5, Fitaihab block 8, Rief el Gunubi, and the Industrial area (belong to Omdurman locality), and West Libya Amra, Gita' el Salam block 28, Gita' el Salam block 13, Gita' el Salam block 15, El Fasaha el Hawair (belong to Umm bedda locality.

The questionnaires:

Three questionnaires were designed and conducted during April 2011. The first questionnaire was directed to the administrations of the tanneries. The questionnaire dealt with information about raw material, , production, types of chemicals applied into tanning, tanning stages, refuse of water and disposal of solid or liquid waste. The second questionnaire was directed to the labourers involved into tanning so as to investigate their socioeconomic characteristics, how do they deal with chemicals, and vulnerability to health hazards associated with chemicals applied. Whole of the society of the 82 labourers was investigated. The third questionnaire was directed to the residents of the area close to the tanneries and 70 individuals were investigated according to time of availability during the fieldwork. It was designed to know their views about health hazards relating to traditional tanning in their neighborhood.

Soil and Refuse water Samples:

The Twelve tanneries were numbered from 1 to 12 in order to choose three tanneries randomly to take soil samples which were El Fitaihab (Block 8), Gita' el Salam block 13 (Umm Baddah), and industrial area (Figure 2). Each soil sample was taken from the three selected sites by digging a hole of 20 – 25 cm depth to get 100 gram of soil material. The samples were kept in tight bags to keep them moist. A sample of 100 ml of refuse water was taken from Gita' el Salam blocks 13 (Umm Baddah) tanneries.

Chemical tests:

Measurement of soil salinity was done by using a pH miler. Carbonates and bicarbonates were standardized with sulphur acid concentration of 0.01. This was done by taking 5 ml of water sample, a soil extract of 1:5 was prepared with 15 gram weight, and then 50 ml of diluted water was added. Mechanical vibrates were used to shake the sample for 30 minutes, which was then filtered so as to obtain pure solution which was then put in standardized flask, and then 3 dots of phenolphthalein were added to get orange color. Three dots of methyl orange were added to form the yellow color which was standardized against sulphur acid till orange color is seen, according to the size of tube burette.

HCO_3 = 1000 ×size of acid used × acid standardization (0.01 M) ÷ size of the sample. These samples were tested during May 2011 in the labs of Faculty of Agriculture, University f Khartoum.

The inputs of raw material and chemicals:

Local market contributes by 82% of skin and hides. Location of tanneries close to Omdurman central market is the main reason for that, as well as supply by small retailers. Imported skin and hides from remote areas was not preferred due to its hardness and high cost, and therefore contributes by 18 %. Raw skin and hides were sorted manually into sheep, goat, and cow types. 63.6% of tanneries use vegetable origin materials such as Mangrove, Tannin, Garad, and Oak, Sindian, Dates, which are available and cheap. Chromium ultra acid, sulphate, and sulphur acid $(SO_4)^{-2}$ are used by 36.4% of the tanneries. Mixed tanning uses both vegetable origin materials and chemicals. However, use of vegetable material or chemicals depends on capital invested into tanning and financial stand of a tannery owner. Chromium contributes by 58.5% of total chemicals. It is used to conserve tanned leather for export. Sulphate, which contributes by 13.4% of total chemicals, is used to remove hair and meat bits, while sulphuric acid is used to remove unpleasant odour produced by chemicals used.

Tanning stages:

Vegetable tanning stages include wetting; liming; removal (unhairing); cleaning; and use of Garad. Wetting stage takes one or two days, when all dry and soft skins are drowned into water. In liming stage, wetted skin is put in basins filled with lime in order to weaken hair and meat bits. Removal of hair (unhairing) and meat bits also requires using basins filled with pigeons' and chickens' excreta (Tarbella), for one day stay. Removal of hair and meat bits is done manually by stretching leather over traditional wooden tools named locally Wargia and Kalouta (scudding). Cleaning stages guarantees removal of all hair and meat bits. In the last stage, skin is put into Garad solution for one day, which wills immediately being dried out.

Mixed tanning stages include wetting; the first stage of removal of hair and meat bits; the second stage of removal of hair and meat bits; cleaning; conservation; and coloring. During wetting stage, skin is drowned in basins filled with water for 12 or 16 hours. In the first stage of removal of hair and meat bits, sulphide and lime are used to weaken hair and meat bits. In the second stage of removal, hair and meat bits are removed either manually or by using some chemicals. Salt solution and Sulphur acid are used into cleaning stage in order to remove lime and sulphide and odour due to using chemicals. In the conservation stage, Chromium and Ultracid are used to prepare finally produced leather for export (Figure 3). Whale liver oil and coloring vegetables are used in coloring stage.

Type of animal skin determines length of tanning period as indicated by 98.8% of the interviewees. This is coincided with the nature of animal skin tanned. Cows have thick and strong skin, opposite to goats', while camels have multilayered skin that needs more processing. In vegetable tanning cows' skin take nearly one month to be tanned, while goats' skin needs nearly 10 days.

Figure 3: Photograph of Produced leather

Source, Africa our continent issue 7 2015: Leather industry in Sudan

Production:

Daily amounts, total daily and total annual of produced tanned leather by types of animal are shown in table 1. Production varies by type of tanned skin, and geographic location of a tannery. The daily total production ranges between 7 and 23 ton per a tannery. One ton difference of production was recorded among some tanneries. The average daily production is 14.72 ton per a tannery which is almost the mid value between lower and higher values of the range. Sheep skin is more tanned than goats' and cows', where it exceeds cows' by nine tons and goats' by almost 18 tons.

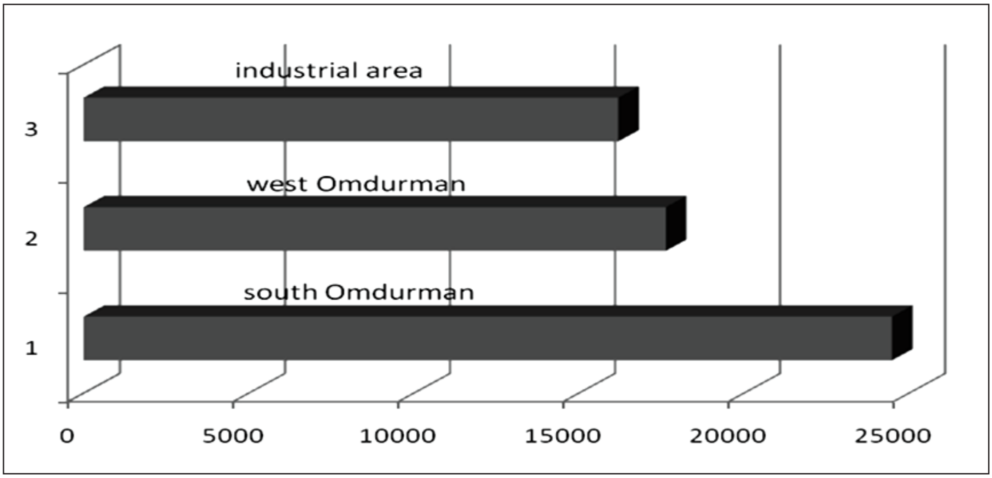
Daily production by ton by geographic area ranks west Omdurman first, where 68 tons of tanned leather is produced per day. It includes tanneries numbered 7-11in table 1. South Omdurman comes second producing 49 of tanned leather per day, including tanneries numbered 1-4 in table 1.The industrial area comes third with 46 tons daily production, with tanneries numbered 5 and 6. Differences in daily production might due to differences in number of tanneries, amount of capital invested, type of tanning, and neighboring to local markets which supply raw material. In some remote tanneries, including rief el gunubi, and el fasaha elhawair, raw material was supplied via middlemen, which rates high cost of production.

Table (1): Daily and annual production of tanned skin by type and amount (Ton)

Area		location	Daily Amount (cows)	Daily Amount (goat)	Daily Amount (sheep)	Total (Daily)	Total (Annual)
South Omdurman	1	Abuseed (Block 7)	4	3	4	11	3960
	2	Fitaihab (Block 5)	3	2	10	15	5400
	3	Fitaihab (Block 8)	1	3	3	07	2520
	4	Rief el Gunubi	7	4	5	16	5760
Total						49	17640
Industrial area	5	Industrial area	10	3	10	23	8280
	6	Industrial area	8	6	8	22	7920
						46	16200
West Omdurman	7	West Libya Amra	2	4	2	08	2880
	8	Gita' el Salam (Block 28)	4	4	4	12	4320
	9	Gita' el Salam (Block 13)	4	7	4	15	5400
	10	Gita' el Salam (Block 15)	6	5	6	17	6120
	11	El Fasaha el Hawair	5	4	7	16	5760
total						68	24488
Grand Total		11	54	45	63	162	58328

The total annual production of leather by major geographic areas in ton is shown in figure 4 which further revealed geographic variations and could give an idea about the expected amounts of refuse water and chemicals.

Figure 4: Total annual production of leather in ton by major geographic areas



Source: Fieldwork, 2011

Refuse by stages of tanning:

Successive stages of tanning produce various types of refuse, where tanning of one ton of leather produces 53 cubic meter of refuse water according to 93% of the labourers. Wetting stage refuses liquid water contaminated with dirty blood, and some suspended organic matters such as fats, which are discharged into the immediate vicinity of tanneries. Liming stage refuses hair, and meat bits, while the removal stage refuses hair, meat bits, and some sorted out low quality leather, dirt, water contaminated with chemicals and vegetable materials, as well as emission of some gases produced from preparation of chromium and ammonia. Both solid and liquid refuse are disposed without treatment in the immediate vicinity of tanneries. The cleaning stage in vegetable tanning refuses hair, and meat bits, while mixed tanning refuses salt solutions, sulphuric acid, sodium chloride, and lime solution. The final stage of tanning refuses water containing chromium, ultracid, vegetable and chemical colorings and oil.

Solid waste is treated by dumping as indicated by 24% of the interviewees. This distorts the landscape and produces unpleasant odour. Burning of solid wastes was confirmed by 52.4% of them, and this annoys people and pollutes the environment. According to 23.3% of the interviewees, burning of solid wastes is done without any technical supervision. These practices cover small amounts of solid wastes and therefore, huge heaps are left behind without any sort of treatment, which consequently distort the landscape and create a niche for insect breeding, unpleasant odour, and health hazards.

Contaminated water of tanning is treated by using sewerage system only in tannery investigated in the industrial area of Omdurman, and was practiced by 6.1% of total tanneries investigated. Use of septic tanks is confined to 34.1% of all tanneries. Here, refuse water was kept in order to be treated later. The field work observations confirmed that, there was no proper treatment. In addition, disposing of refuse water without any treatment in the open space around tanneries is practiced by 58.5% of the tanneries and 70% of the residents neighboring these tanneries confirmed that. This makes it hazardous to soil and subsoil water used for human consumption (table 2).

Water and soil samples results:

The soil sample test in table 2 depicts that, the pH value exceeds three times the lower permitted limit, and even exceeded the upper limit by a small fraction. Electric conductivity of the soil sample is ten times higher than the lower permitted limit, and four times higher the upper one. Carbonate is absent, while bicarbonates value exceeded ten times the upper permitted limit of 50 ppm, whilst for sodium it nearly exceeded the permitted limit seventy times. The estimated acidity of chemicals in soil is five times higher than the upper limit. Sulphate sulphide is less than the permitted level, and for chromium it is almost close to the upper limit of 170 ppm. This confirms that water contaminated with chemicals refused in the immediate vicinity of tanneries pollutes soil.

Water sample results in table 2 depicts that, pH value is higher than the lower permitted ratio, but is less than the upper one. Electric conductivity of the water sample is 16 times higher than the upper permitted limit, while Carbon and Bicarbonate were absent. Also, sodium ratio exceeded by 884 times the upper acceptable limit, and similarly estimated acidity is 356 times higher than that limit. Sulphate sulphide is three times higher than the upper limit, and chromium ratio is 37 times more over the upper limit.

Table (2): Results of ratio of used chemicals in soil and water samples

	Name and symbol	Acceptable ratio	Soil sample result	Water sample result
1	pH	2.5 – 7 ppm	7.35 ppm	3.78 ppm (-)
2	E. conductivity (Ec de/m)	1-4 ppm	11 ppm	64 ppm (16 times)
3	Carbonate (Co_3)	1-4 ppm	0.00 ppm	0.00 ppm
4	Bicarbonates (HCO_3)	20-50 ppm	561.2 ppm	0.00 ppm
5	Sodium (Na^+)	20-50 ppm	3560 ppm	44200 ppm (884 times)
6	Estimated acidity (H_2 SO_4)	1-4 ppm	20 ppm	1425 ppm (356 times)
7	Sulphate sulphide (S- SO_4)	5 -10 ppm	1.27 ppm	31.91 ppm (3 times)
8	Chromium (Cr)	30-170 ppm	193 ppm	6400 (37 times)

Source: Fieldwork, 2011

Labourers' socioeconomic characteristics:

The interviewee labourers lay within the 16-30, 30-45, 45-60, and 60+ age groups. Those aged 16 to 30 years old represents 31.7% of the total, and responsible of the laborious sorting and holding of leather. Those aged 30-45 represents 40.2% of the total, and work as supervisors on those aged 16-30, as well as taking responsibility of counting pieces of leather, and the amount of chemicals used. On the other hand, those aged 45-60 years old are the senior supervisors and the most experienced group, who are responsible of quality control and leather marketing. Those aged 60 years and above are generally the owners and managers of the tanneries. The survey results conducted among tanneries' administrations revealed that, 90% of the tanneries work continuously while 9.1% work seasonally.

The majority of the labourers (79.3%) are illiterate, (14.6%) did not complete basic education, 6.1% completed intermediate school; and some few others have got religious education. Places of origin of the labourers are White Nile state (69.5%), Darfur; and Kordofan states, with a former background as subsistent peasants. Permanent Labourers constitute 78%, while seasonal labourers constitute 22%. Experience in traditional tanning differs among labourers, where 42.7% of them have spent less than 10 years; 57.3% more than 10 years, while very few have long experience who own the tanneries. Labourers income varies between tanneries highly tied with experience, work type, and amount of production. Labourers wage payee is either per day (45%) or per week (54.5%) based on amount of production, type of tanning, either vegetable or chemical tanning. Wage payee is lower for vegetable tanning compared to chemical tanning.

Environmental impacts on geographic neighbourhood:

The majority of the inhabitants (72.7%) living in nearby residential areas to the tanneries work neither in tanning nor in other related activities. They generally have rural background, while very few have come from old residential areas of Omdurman town. They have agreed (100%) on the difficulty of living here because of unpleasant odour; refuse water and disposal of solid wastes of tanning. The nature of climate and the clayey soil help the long stay of refuse water and slow decay of organic matter. The majority of the residents (70%) suffer respiratory diseases, particularly allergy, skin diseases (23.5%), eye diseases (4.3%), and digestive system related diseases (2.7%). In their own point of view, this is because of tanning processes which use chemicals and emit gases. A percent of 66% of the residents indicated to continuous recurring of these diseases all seasons of the year, while 34% have denied that. In addition, 65% of these residents confirmed the influence the internal environment of their houses by unpleasant odour emitted from tanneries, and they majority (87.1%) have agreed on that heaps of disposed solid waste distorts the landscape, which is furthers exacerbated by high residential density, stagnant water during the rainy season (100%), and almost complete absence of waste management by local authority.

Discussion:

Based on the two main findings of this study that, traditional tanning is a major source of environmental pollution, and the workers involved in this activity, as well as those living nearby to the tanneries, are urban poor with a rural background, our discussion will proceed on. It is evident that hazardous wastes in our case study are liquid, solid, poisonous gaseous emissions, or sludge and contain chemicals, heavy metals, dangerous pathogens, or other toxins. Also, it is certain that tannery waste characteristically contains a complex mixture of both organic and inorganic pollutants. Related studies could further support our cases by the fact that tannery industry consumes hazardous chemicals and generates potentially harmful solid waste, effluents and emissions (FMAI (2012), and chlorinated phenols and chromium were found to be closely associated with the tannery waste (Reemste and Jekel 1997; Mwinyihija et al. 2005, 2006), and by the fact that European tanneries produce, on average, 2.14 kilograms of waste for every square meter produced which is environmentally significant value (Social and Environmental Report the European leather industry 2012).

Soil samples analysis in our case study conforms to some studies on the properties of soils collected from some tannery areas which revealed that soluble, particularly Ca and Mg from tannery effluents could enhance soil cation exchange capacity. Furthermore, the threat of tanneries effluents in our case study to pollute water sources is supported by a study on the water quality of the river Buriganga in Bangladesh where tannery effluents heavily polluted the river water (Imamul, no date), a situation similar to other locations in Sub- Saharan Africa and to Kanpur in India, where about 80% of the wastewater is untreated and dumped straight into Kanpur's main water source.

Concerning the other main finding that, workers involved in this activity are urban poor with an impoverished rural background and those living nearby to the tanneries have no choice other than to stay there, conforms to the fact that human poverty in Sudan remained high, and geographically maintained clear differences, and linked with low Income. It, furthermore, conforms to the situation that the majority of Sudanese are involved in related agricultural activities, where agricultural poverty prevails in almost all regions of Sudan with more emphasis in Darfur, Kordofan, and Eastern regions which are largely involved in rainfed agriculture and showed irrational management, poor investment, deteriorating resources, and decreasing productivity (Hamid Faki, el al.,. 2012). The increase in rural poverty in almost all regions of Sudan supports the content on that the negative impact of adjustment and liberalization policies, which were implemented since 1990, has reached the rural areas and hit them hard. In addition, people of these regions share rural Africans in causes to move to urban areas which will witness an increase in population by 43% in the year 2025 (UN Habitat, 1996), due to poor living conditions, poverty, decline of the standard of living and critical natural hazards of drought, flood and famine (Adepoju 1990; Oucho 1998). These migrants conforms to the life cycle approach which states that interactions of an individual life events shape the decision to migrate over the lifetime (Kulu and Milewski 2006), and with Matt and Bruce (2005), who stated that impoverished rural places are often depicted as immobile communities populated by less skilled, less educated non-movers who have been left behind by selective out-migrants and were reduced to poverty (Free Dictionary, 2011), which is similar to several African and Asian countries, where the numbers of the urban poor have increased with some urban scholars labeling it as "urbanization of poverty" (Urban Poverty in Asia Publication, 2014). Although of the fact that, urban growth in sub- Saharan Africa is higher than the World average (Bocquier 2005), where sub- Saharan Africa had experienced declining urban growth during 1990s and 2000s (Bocquier 2003; Bocquier and Traoré 2000), which suggests that migration has contributed even less to urban growth in the recent past in Africa (Potts 2006).

The population growth rate in Sudan was 2.5% in 2007, and 40% of the population lives in urban areas (The World Bank 2008) and the percentage of urban population is projected to be 46.4% in 2025 while it was 24.2 in 1994 (UN, 1994), and has increased from 8% in the year 1956 up to 29% in the 2008 (CBS, or to 40% (MWSS, 2010), with a general world trend of growth of squatter settlements which constitute 20 to 80 % of urban settlements in developing countries (ECOSOC, 2005).

Although Sudan is rich in natural and human resources, 77.5% of the households surveyed in north Sudan were on or below the poverty line (MOL and ILO, 1997]. The study by the United Nations Development Program in 2005 reported that 75% of north Sudan population as poor and the majority (80%) is concentrating in rural areas where 30% of them suffered from extreme poverty (United Nations Development Program, 2005). Dominance of Low income groups in our study area agrees with the fact that more than half of the urban dwellers in Sudan are living under the poverty line, which is applicable to 90 percent of the total population of the country (Mahran, 2006), and with figures in

Sub–Saharan Africa where about half the population is living below the poverty line, with both numbers and percentage on the increase (Alredaisy, et al., 2001), and with the fact that, rapid urbanization in Sudan led to the increase of low income squatter settlements which receive rural migrants and intra-urban movements (Muindi et al. 2009). These squatter settlements provide the essential labour-force to work in the industrial and commercial sectors of the cities where 65% of the urban dwellers in Sudan operate in the informal sector, according to Eltayeb (2003), while it was 50% according to UNDP (2006) and the distinction between the formal and informal sectors is getting blurred in Sudan at present. These areas, furthermore, have population below the poverty line, overcrowding and lack of access to facilities (Ali et al., 2004) which further conforms with world figures in 2003 where nearly one sixth of the world's total population is slums dwellers (UN-Habitat, 2003).

The World Bank (2014) noted that the percentage of poor people in the capital Khartoum has increased by at least 25%, and provides evidence of high income poverty between 1990 and 1996 which ranged from 91% to 93%, and was particularly higher in Darfur and Kordofan (The Sudan Institutional Capacity Program, 2011). Generally, growth of towns and cities in Sudan has been accompanied by growing numbers of poor and vulnerable urban dwellers (Sara Pavanello, 2011), and Figure (5) illustrates that.

Figure 5: Poverty in Khartoum.

Source: http://www.poverties.org/blog/poverty-in-sudan

The access to safe and sustainable livelihoods by these urban poor is extremely unstable (Sara Pavanello, 2011). However, factors influencing income attainment in the study area might include those operating at the national level including absence of social development and insufficient productive capital investment (UNDP, 1998), ill-conceived development policies and armed conflicts (Zeng, 2003), and privatization policies which were launched by The National Salvation Economic Program in 1993 as State's policy, which was based on uplift of financial subsidy in situations of deteriorating agricultural production; marketing and production problems; devaluation of the national currency and political unrest (MFEP, 1993). The government low expenditures on agriculture and forestry are similar to many African countries where between 1988 and 1993, agricultural expenditures had generally declined and constitute 1.5% and then 7.9% of total expenditure (Derrick, 1987). The relationship between the rate of increase of agricultural output and changes in the incidence of rural poverty, using Indian data, which is similar to African data, according to Keith (1979) has shown little reason to believe that poverty will diminish significantly merely by accelerating the growth of production. The causes of impoverishment have more to do with the pattern of growth than with its rate. The problems of poverty and impoverishment in African and some Asian rural societies, which could be applicable to Sudan, are social, economical, psychological and ecological factors which affect the nature and course of impoverishment and deprivation in these communities (Keith, 1979).

Conclusion:

The general conclusion one could emerge with it from the above mentioned discussion is that, traditional tanning in Omdurman is an implication of environmental, socioeconomic, and political problems that tightly connected with the general situation of the country. Therefore, the proposed figure (6) in our case summarized the above mentioned discussion into five interrelated cells. It depicted the causes, the consequences, and the proposed policies into a broader national dimension. The specific proposed policies in the fifth cell in figure 6 are interrelated with those general policies proposed in the fourth cell.

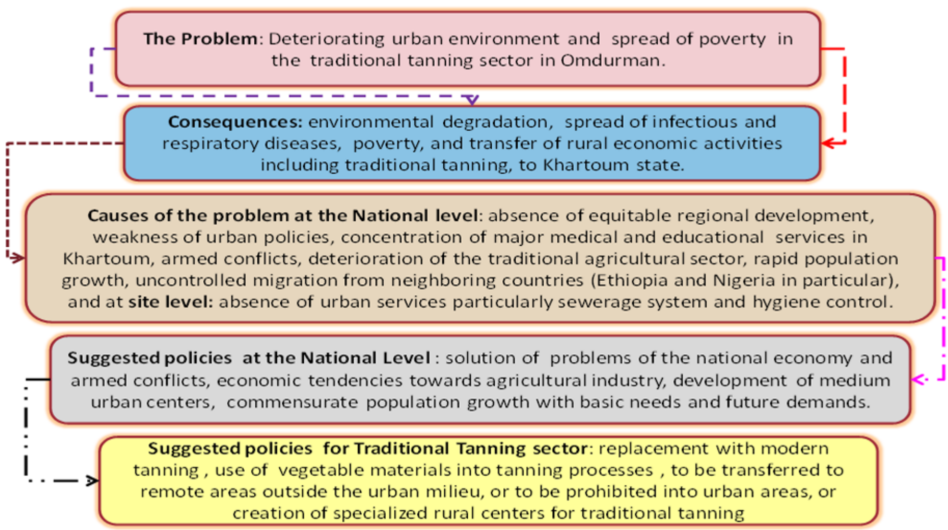


Fig. 6: Suggested policies to reduce environmental impacts of traditional tanning and to alleviate urban poverty in Sudan

The authors called for transfer of traditional tanning in Omdurman to some remote rural areas with open space, away from human concentrations, where raw materials of skins and hides, and environment friendly vegetable products used in traditional tanning are easily available, and where workers could easily live in their villages without any economic burden as that needed to urban living. This could be part of the call for a new system of environment friendly tanning process by Anna Bacardit and others (2014) who have stated that "What is obtained through this new process is leather free of chromium, aldehydes, aldehyde precursors and organic solvents. This new system consists of the application of Tanfor T_system (from Kemira), which is safe for both humans and the environment and is not classified as hazardous. When compared to existing traditional processes, namely chrome tanned leather (Wet-Blue) and aldehyde tanned leather (Wet-White), there are economic and environmental advantages resulting from the use of this new system".

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8

Socioeconomic and environmental implications of Traditional Gold Mining in Barber Locality, River Nile State, Sudan

8

Socioeconomic and environmental implications of Traditional Gold Mining in Barber Locality, River Nile State, Sudan (*)

Since ancient times gold was a main reason for migration, and in modern history the late nineteenth century witnessed the most extensive and famous series of gold migration (Raymond, 1999). Sudan is famous with gold since ancient times as evident by archeological discoveries of golden artifacts and tools in the Kings' graves of ancient kingdoms, and it was the main reason behind Turkish invasion to Sudan in 1820. Gold associates with igneous, metamorphic, and sedimentary rocks which make up basement complex of Sudan (GRAS 2006, Whiteman 1971). With the exclusion of superficial deposits, basement complex includes by percent 49% basement complex rocks, 48% sedimentary rocks, and 3% recent deposits (GRAS, 2006). The lower mantle of igneous rocks of Donite and Harzburgite contain chromium and platinum in Ingassana and Red Sea Hills, and the Nuba Mountains. Copper, Nickel, Platinum of Kambalda type associate with Gabbro, Perodotite, and Harzburgite rocks of Ingassana, Wadi Amir and Onib area in red Sea Hills. Also, gold associates with acid volcanic rocks of Ariab area of Red Sea Hills,

(*) Co- authored with Altayeb Ahmed Wadi, University of Khartoum, Dept. of Geography.

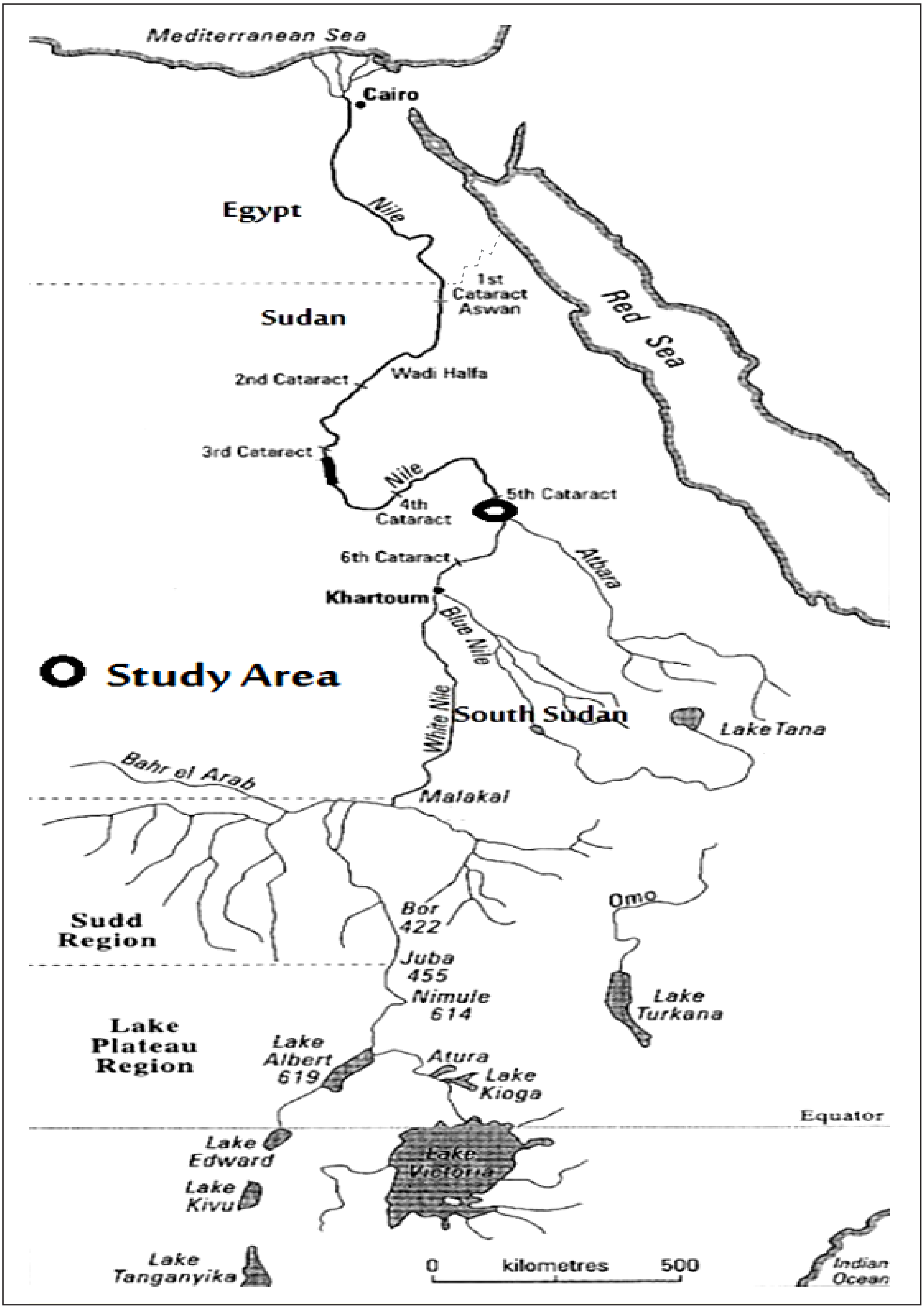
the eastern parts of Ingassana Hills, the Nuba Mountains, Hofrat Al Nahas in Darfur, and eastern Wadi Halfa, and Gabgaba Wadi in northern Sudan (Embassy of the Sudan in South Africa, 2006).

The first gold amalgamation activities in Sudan were done by British small–scale mining companies in Red Sea Hills and Northern Sudan, when they were intermittently operating during 1904–50s (Ibrahim:2003). Recently, gold mining is found in 14 out of 16 states of Sudan. This culminates with 91 big companies; 590 small companies; and 106 sites of traditional gold mining (Khartoum Journal, 2013); which involves the use of simple manual tools of shovels, pickaxes, hammers, chisels and pans in both surface and underground environments (Aryee et al., 2003). As a result of secession of South Sudan in 2011 and loss of petroleum profits which contributed by 50% to national income, gold has been counted by the government as part of the important economic resources in Sudan. However, about 90% of the annually produced gold in Sudan comes from traditional mining which absorbs about 5 million miners and other workers of accompanying jobs, while those affected by this activity are estimate at 11 million people (Sudanow, 2014).

Study area and fieldwork:

The study area locates in River Nile State, northern Sudan, between latitude and longitudes (Fig.1). It has an area of 122,123 square km and a population size of 1000000 persons in 2006. The prominent geomorphic feature, here, is the fifth cataract (Fig.1) of the River Nile which follows the oldest pre- Cambrian geologic structures (Stern et. al, 1997). Hudi deposits appear east of the Nile between Khartoum and Berber. These deposits represent a type of lacustrine deposition during Oligocene. It directly cover the Nubian gravel, and might be covered by basalt resulted from more recent volcanic activity. In the study area there are spots of rocky hills desert with more than 1000 m elevation, crossed by Atmour valley and is considered as part of Red Sea Hills, (GRAS, 1995).

Fig.1. Location of study area



Bayouda desert is an area of rocky sandy desert composed of basement rocks and lava fields associated with Cenozoic and cinder cone complexes date back to Devonian. The majority of the remaining of Bayouda desert is a rocky sandy desert with scarps and plateaux of sedimentary rocks date to Mesozoic separated by open sandy plains and inactive Qoz areas. The River Atbara (Fig 1), to the south of the study area, is a location of a garben occurred during Mesozoic and runs over a flood plain covered by recent fluvial deposits. All these geologic structures could be suspected for gold excavation. Bayouda formation includes Abisol, Kurmuk, Rahaba, and Abuharig series. Auharig series was distinguished by Vail (1979) as to belong to grey Gneisses group, while the first three groups belong to metasedimentary group.

Methodology:

The fieldwork was carried out during June 2014 in Alebedia area (Fig 1), Berber Locality in the River Nile State. Two groups of gold based workers were investigated, who were gold field miners and gold treatment workers. The first group concerns with excavation; collection of stones and gold pieces; stone crushing and packaging (Photo.1). The second group concerns with works of stone gridding, washing, separation, and refinement of gold (Photo.2). The sample size for the first group was 35 persons, and for the second group were 25 persons with a total of 60 persons. The authors consider this sample size is representative of the population, since there is lack of official data of traditional gold workers, financial difficulties, and insecurity to reach remote areas of traditional gold mining. They were interviewed according to their accessibility during time of the field (nonprobability sampling procedure). The questionnaire included both groups' socioeconomic characteristics, the nature of their works, available medical and water services, work environment, and their views towards solving the current problems they face.

Photo.1. Gold excavation

Photo.2: Gold refinement

Miners' socioeconomic characteristics:

The majority of the workers lie within the age group of 20 to 30 years old, and few aged less than 20 or more than 60 years old. Putting the two age groups of 20-30 and 30-60 together gives a percent of 93.4%, which obviously distinguishes the workers as young and economically active group of population. This also indicates to traditional gold mining as effective pulling factor in population movement in Sudan, regardless of the migrants' educational attainment; marital status; and place of origin. This is seen in table 1, when nearly 1/3 of the population has graduated from a university, or completed secondary education. The reflections here are that, there is lack of job opportunities provided by the government or by the private sector to accept university graduates, and also, to the failure of the so called higher education revolution of 1994 to provide technical cadres for the labor market in Sudan, since there was wide expansion in theoretical studies rather than technical ones. Putting in mind the prevalence of youngsters among these workers, however, those who have completed basic education could be considered as school leavers, while who aged than less than 20 years old as child labor. This is a reflection of school dropout as the Sudanese majority could not afford educational costs. It could be also a reflection for unrest in Darfur, southern Blue Nile, and southern Kordofan. Also, table 1 presents 65% of the workers as single, in a situation where those aged 20-30 years represents 66.7% of the workers. This is means that they either work to support their mother families, or collecting money to get married since average age of marriage in Sudan is above 25 years, or some are under age of marriage. The reflection here is that, the existence of only masculine identities, with dangerous working conditions, might make miners vulnerable to homosexuality and HIV infection, violence and committing crimes. However, Immediacy of the study area to Khartoum and central States was reflected on the high percentage of 80% of the workers who engaged in mining in the study area. Although Darfur and Kordofan are geographically remote from the study area, nearly half a third of the workers came from there (Photo.3). This is a reflection of the fact that, these areas also have their own areas of traditional gold mining (Photo. 3). Although the Northern State is geographically neighboring the study area, it had contributed low by workers. This is a reflection of the preference of northerners to work in Gulf States, as well as being educated to employ civil jobs. Monthly income of the majority of gold miners ranges between 500-1000 SDG (Table 1), which equals 60-120 USD/month, or 2- 4 USD/ day. However, 20% of the workers earn 2 or 1 SDG/ day which distinguish them as poor, and even those who earn more than 4 USD / day they could not escape poverty.

Photo.3. Traditional gold mining in Darfur
Photo credit El-Tayeb Wadi

Table 1: Socioeconomic characteristics of traditional gold miners in the study area

Characteristic	Groups	Frequency	Percentage
Age groups	Less than 20	2	3.3
	20-30	40	66.7
	30-60	16	26.7
	More than 60	**2**	**3.3**
Educational Attainment	Uneducated	5	8.3
	Basic education	23	38.3
	Secondary education	14	28.3
	University	**18**	**30**
Marital status	Single	39	65
	Married	**21**	**35**
Place of origin by states	Khartoum	37	61.7
	Central	11	18.3
	Western	10	16.7
	Northern	**2**	**3.3**
Previous work	Idle	1	1.7
	Student	24	40
	Worker	31	51.7
	Trader	**4**	**6.7**
Date of coming by years	Less than 3	24	45
	3 – 6	17	28.3
	More than 3	**16**	**26.7**
Monthly income SDG	250-500	12	20
	500-1000	26	43.3
	More than 1000	**22**	**36.7**

Source: Fieldwork, 2014

Miners’ environmental health conditions:

Workers consume dirty water which is insufficient and expensive (Table 2). This gives the reflection of water unreliability, unaffordability and unavailability in gold mining areas. These deficiencies in water supply and quality bring these workers to risks of water washed and water borne diseases such as diarrhea, dysentery, typhoid, and cholera. This could be more worsened by lack of sufficient and good quality food, affordable food prices which were confirmed in table (2). The reflections are susceptibility to disease infection, malnutrition diseases, and morbidity. Since, there is lack of basic medical services in the study area (Table 2); there are records of infectious and respiratory diseases. In March 2011 Abu Hamad’s central hospital received 107 cases of undiagnosed fever from gold mining areas, in addition to some cases of cancer and respiratory diseases. This is because gold miners use mercury and cyanide for gold extraction, where one gram of gold requires 1.5 gram of mercury (Mohammed, 2003). Mercury goes into the human body through inhalation or by eating polluted food or water, as confirmed in the study area, where RASAS was found in the blood of 48% of miners (Ashri, 2012). However, in a desert condition such as that of the study area, there is a risk of Sun stroke when temperature reaches 50^0 C during summer. Collapse of mines is one of the main challenges. Digging process may take place at the bottom of 40 meters below the earth surface. The incidence of land mine collapse of Jebel Amer in Darfur killed about 100 miners in 2011. Absence and poor rescuer process may contribute to add to.

Table 2: Miners' environmental health conditions

Service	Characteristic	Frequency	Percentage
Water supply	dirty	12	20
	expensive	34	47
	Insufficient	**14**	**23**
Food supply	worse	15	25
	Expensive	31	35
	Insufficient	**24**	**40**
Medical services	Clinic	7	11.7
	Dressing point	5	8.3
	Shop	35	59.4
	Nearest town	**13**	**21.7**
Common Diseases	Respiratory	10	16.7
	Gastrointestinal	1	1.7
	Malaria	6	10.0
	Fever	1	1.7
	Insect bites	**1**	**1.7**

Source: Fieldwork, 2014

Discussion:

Despite the economic importance of gold mining, it has very costive environmental impacts such as air and land pollution, clear of vegetation cover, deterioration of wild life as well as the it effect on agricultural activities. The main serious problems of traditional gold mining ar, the increase of school dropout, child abuse, robbery, drugs, and sex, armed robbery, lack of security services, lack of public services and conflicts over concessions areas. Prevalence of HIV and other STI is high among migrant mining workers due to factors such as dangerous working conditions, only masculine identities existence, living away from families, desolate and in hospitable place. This makes them known to be HIV and STI vulnerable group in different part of the world. The HIV preventive behavior of the mining worker was low. Less than half of the respondents 187(47.6%) were engaged in HIV preventive behavior. HIV preventive behavior is negatively associated with being in middle, higher and highest income, and positively associated with Completing secondary, tertiary school and self-efficacy. Thus this population group should be understood as at risk population at national level (Hordofa, et al., 2014).

18% of the suspected cases of viral haemorrhagic yellow fever outbreak on 1st of October 2012 in Darfur were traditional gold mining workers (Elhassan, et al., 2012). Also adults in Khossanto and Fongolimbi rural communities (gold mining sites) were significantly less immunized against YF than those in Kedougou town with respectively OR=0.31[0.16-0.58] and OR=0.62 [0.39-0.97] (A. Sow, et al., 2012). Health problems of gold miners who worked underground include decreased life expectancy; increased frequency of cancer of the trachea, bronchus, lung, stomach, and liver; increased frequency of pulmonary tuberculosis (PTB), silicosis, and pleural diseases; increased frequency of insect-borne diseases, such as malaria and dengue fever; noise-induced hearing loss; increased prevalence of certain bacterial and viral diseases; and diseases of the blood, skin, and musculoskeletal system. These problems are briefly documented in gold miners from Australia, North America, South America, and Africa. In general, HIV infection or excessive alcohol and tobacco consumption tended to exacerbate existing health problems. Miners who used elemental mercury to amalgamate and extract gold were heavily contaminated with mercury. Among individuals exposed occupationally, concentrations of mercury in their air, fish diet, hair, urine, blood, and other tissues significantly exceeded all criteria proposed by various national and international regulatory agencies for protection of human health (Eisler, 2003).

Conclusions:

The research revealed that mining activities have resulted in land degradation leading to limited land available for local food production and other agricultural purposes in the Obuasi municipality. In addition, there is pollution which has affected mainly water resources in the area with major streams like Kwabrafo, Pompo, Nyam, San and Akapori 51measures being put in place by the mining companies have not sufficiently addressed the problem of noise pollution in the area (Joseph, 2008).

Various publications on the gold-mining areas in Bolívar State have mentioned a sharp rise in violence and alcohol and drug abuse (4), which are directly linked to the practice of unsafe sex. There are reasons to believe that gold-mining sites may also be characterized by what is called "situational bisexual and/or homosexual behavior." Records of STD clinics in this area indicate that each week an average of 2530% of all individuals seeking counseling test positive for at least one STD. The incidence of STDs among indigenous populations in gold-mining areas of Bolívar State is on the rise (Lily, et al., 1999).

Miners in South Africa's gold mines have the highest rates of tuberculosis (TB) infection in the world. The rate of TB infection among miners is between 3,000 and 7,000 per 100,000 populations - between four and seven times higher than the generalpopulation of South Africa, the country with the second highest TB rates in the world. Men arriving at the mines to work, becoming infected with TB and returning home again – has created an enormous public health crisis throughout the region (Saoirse, et al., 2013)

Mining has an impact on general population risk of TB in Southern Africa, making it a public health issue. 10% increase in mining production there will be an increaseby à1% in TB incidence (23 000 cases). ''mining not only increases the hazards of TB among directly exposed individual miners but significantly increases the risks of TB spread to the general community in sub-Saharan African countries".1Huge health system challenges of treating a very large silica exposed/silicotic migrant population across a number of countries, against a background of rising drug resistance''(Reddy, 2005)

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9

Deterioration of Acacia in western Butana plain, Sudan

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Deterioration of Acacia in western Butana plain, Sudan(*)

Acacia is a Greek word means ''thorns'', which is a Genus for trees and shrubs of Mimosaceane family. They are drought resisting trees where there are more than 300 types of Acacia in Australia, 1000 in America while there are more than 400 types in Africa and Asia with restricted types in arid and semi arid parts. Many types of Acacia exist together such as Simaroubaceae, Capparideceae and Tamaricaceae and Rhamnaceae. They are identical and sensitive to climate and soil factors and therefore, they occur in forms of dense or sparse forests, except those ones subjected to human interference. There are many types of succulent; non-succulent and evergreen perennials Acacia. Succulent Acacia store water in their stems for times of water deficiency while the non succulent Acacia extend their roots deep into the soil searching for water, and the evergreens have adapted to resist drought (Walton, 1979; Hills, 1966; Clarke, 1954). Stebbing (1972) indicated to the dense tropical forests which used to cover most areas of Sudan. Wormond (1939) explained that the Sahara desert was flourished with animal and plant life where fossil trees, buried valleys are evident.

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Lavadan (1944) mentioned many clues that tropical forests were near to Cairo up to mid Pleistocene. Walton (1979), Nichelson (1978, 1981) studied paleoclimate of the Sahelian zone and explained that there were warm, rainy and humid periods and there were also dry periods. Before 18,000 years ago, these areas witnessed a drought period which led to formation of sand dunes and drying up of lakes. In the last 12,000 years climatic conditions changed to heavy rains, while the last 3,000 years rainfall decreased which lands exposed to erosion and deposition processes when recent sand dunes were formed.

The present investigation assesses spatial variability of Acacia deterioration and the contribution of natural and human factors that resulted in that deterioration in western Butana area. This deterioration suggests a run down of the natural resources in the region. Furthermore, this area was classified by the UN Conference of 1977 as being under ''Very High Risk'' of desertification (Fig.1). This paper examines deterioration of Acacia that has occurred within this region by looking at the results of a survey carried out in 2005 and the notification of studies covering the period from 1928 to 1999.

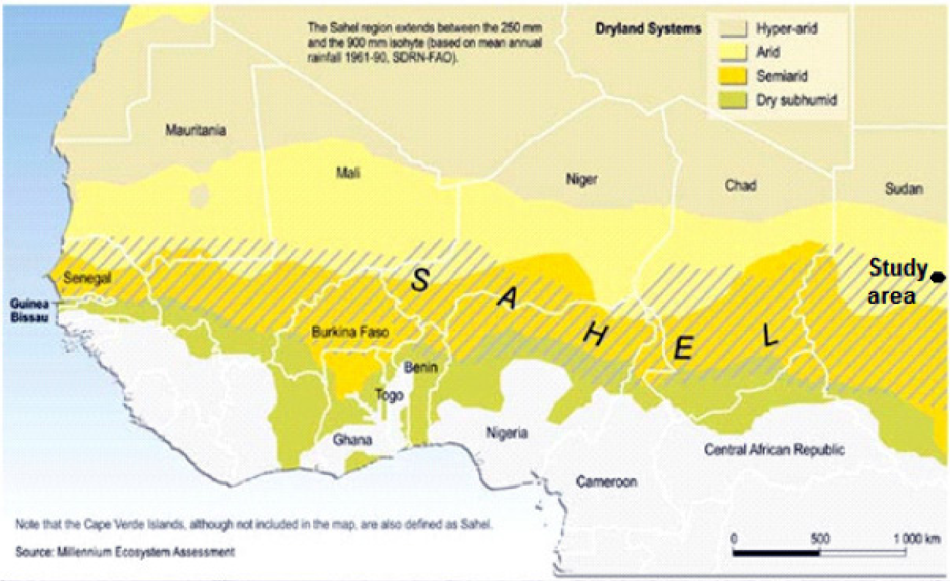


Figure 1. Dry land system and location of the study area in the Sahel. Source: After Millennium Ecosystem Assessment.

Data and study area:

The study area of western Butana of Sudan is lying between the Blue Nile in the west and Sahara desert in the north at 14 – 16 N and 33 – 35 E. The area is chosen because it is one of the most hit by Acacia deterioration in Sudan. Physically, the study area is part of the Butana region which is a plain surface intermitted by dispersed hills covered with alluvium. Topography of Butana includes three major units. Firstly, highlands and isolated mountains in the southeast. Secondly, plain area dominating the area and characterized by clayey soil (45-80% clay particles) either flat or slow sloped. Thirdly, Wadis (valley) area including depositional areas around seasonal rivers like Atbara and Rahad. Most of the area is underlain by Basement Complex of Tertiary Basalts both of which provide little water except in the detrital material around the occasional hills and small supplies to be found along joints in the rock (Davies, 1964). Two distinctive climatic belts are found in Butana area. The first one is semi arid climate found in the north and northwest and characterized by summer seasonal rains during July-October. The second one is a wet climate found in the eastern and southern parts of the state with average rainfall of 500-900 mm/ year and maximum mean temperature of 47 ^{0}C.

Data for Acacia is collected by dividing the study area into three main zones indicated to by A,B and C letters according to density and diversity of Acacia and location with respect to the Blue Nile (Fig.2). Area of each square is determined as 10000 m^2 (100 m x 100 m). Midpoint at which the eight major and minor directions meet together is specified at the village of Um Akash (Fig.2). 5 to 7 squares for each direction line, with distance interval of 2-3 km, are chosen. Then vegetative cover is determined following laws for arid lands which include that for each plant type in one square the following should be specified: Number of individuals in one plant type; % of vegetative cover for each plant type; height of a plant; % of frequency; type abundance; type density and number of plants. Following Walton (1979), Hills (1966) and Clarke (1954) Acacia cover in the study is classified into Succulent perennials, non-Succulent perennials and evergreens. Data for soil samples is done by collecting 21 samples from 7 sites (3 for each). Composite samples are done by collecting sufficient number of sub-samples supposed to be representive to the original population. These sub samples are mixed together to produce one composite homogeneous sample. The stage of judgement samples is done from Ahamda forest rom areas differing into vegetative covering density of Acacia tree, dense to sparse to bare of Acacia with depths ranges of 0-15 cm, 15-30 cm to give 30 samples from 15 site. Five soil properties were investigated including pH; E.C; O.C; Na AND Ca and physical properties of Clay – Silt- Sand.

Data for human factors is collected through 200 questionnaires, distributed into 12 villages representing 13% of total number of villages in the study area and also representing 10-15% of total population in each village. In addition, interviewing with eldest persons is run including farmers and grazers to detect old vegetation situation in the area, as well as some government officials.

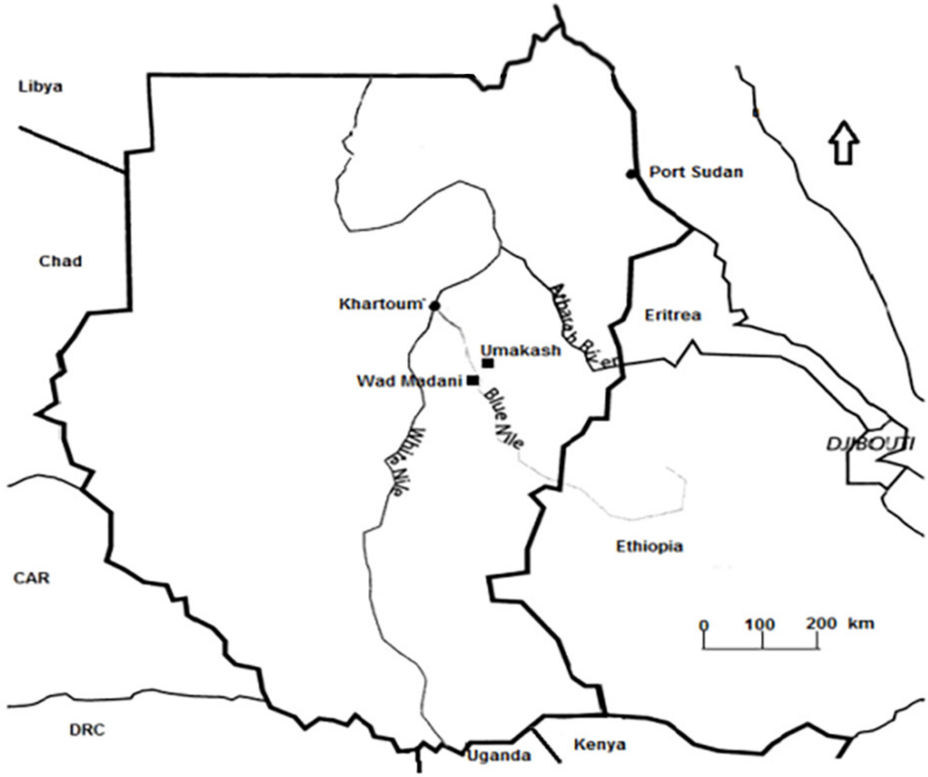


Figure 2. Location of the study area as indicated to by Umakash. Source: After Department of Survey, Sudan 2008.

Measurement methods:

Quantitative methods are applied to calculate coverage, frequency, density and abundance of Acacia. Calculations for abundance (type/ square) = number of individual of one type (A) /number of squares where that type (A) is found. Frequency (%) = no. of squares for one type (A) x 100/total number of squares under study = number %.. Cover (%) = no. of one type x 100 / total of Acacias = number %. Density (type/ a square) = number of individual of one type (A) / total number of the studied squares = number of Acacia/ square. Similarly, descriptive statistical methods are applied on human data.

Spatial patterns of acacia:

The majority of Acacia is non- Succulent and they are differing spatially, by soil type and in cover; frequency; abundance and density (table 1). Zone A has the highest occurrence followed by zone B and C respectively. Acacia tortillis vor raddiana and Acacia nilotica dominate areas close to the Blue Nile in zone A, forming closed forests such as Rufa'a, Dalawat, Hibaika and Ahamda forests. Zone B lies in the middle of the study area which experienced extensive traditional rainfed agriculture where by now there is one tree / 5 feddans (1 feddan =1.038 acres), mostly of Balanites aegyptiaca. Zone C has little Acacia occurrence, mostly of Acacia mellifera. Differences on Acacia occurrences are depicted by soil types (tables 1). Acacia is diverse on clayey soil, and although of that, they are less occurring. On sandy soil, Acacia is more diverse and dispersive but, less denser. On the loamy soil, Acacia nilotica are abundant with few Acacia seyel vor fistula.

Table (1) also depicts cover; frequency; abundance and density of Acacia in the study area. Although these statistics are low in zone A, excepting forests close to the Blue Nile, they are the highest compared to the other two zones. In zone A, Acacia tortillis vor raddiana ranked high by 24.1% cover, 90.9% frequency, 5.9 abundance and 5.4 densities. Figure (2) and fieldwork indicated that, Acacia trees which were dominating in this zone in the past were not only Acacia tortillis vor raddiana, but they were Acacia nobica; Acacia albida, Balanites aegyptiaca and all of Acacia seuel vor seyal; Maerua crassifolia; Acacia tortillis vor tortillis; Acacia seyel vor fistula, all of which are very few at the present time (table 1). Zone B is dominated by Balanites aegyptiaca and A. tortillis vor raddiana, while the remaining Acacia trees did represent more than 5% covering. A. tortillis vor raddiana and Balanites aegyptiaca; Z. spina Christi, A. seyel vor sayal; A. seyel vor sayal; Maerua crassifolia; A. nobica and Capparis deciduas are very rare while they were dominant in the past (Fig.2). Acacia species dominating clayey soil included Schoenefeldia gracilis; Gunandropsis gynandra; Arianthema pentanda; Dipterygium glaucum; I. Semitrijuge and Sorghum spp. On sandy soil, Schoenefeldia gracilis; Cymbopogon nervatus are very rare and there is few Citrusullous colocynthis. In zone c, Tortillis vor raddiana dominates sandy soil by 23% cover, 41.3% frequency, 4.6 abundance and density by 1.9. It is followed by A. nobica with 8.2% cover, 16.6 % frequency, 4 abundance and 0.7 densities. This zone had experienced A. mellifera which formed forests in the past and by now representing 3% of the total Acacia cover. A. seyal vor seyel; A. albida and A. seyel vor fistula have disappeared. Also Blepharis edulis; Arianthema pentandra; Cymbopogen nervatus and Pennisetum pdystachyum have deeply deteriorated.

Table 1. Occurrence of Acacia by zone and soil type; cover; frequency; abundance, density and life cycle in western Butana plain, Sudan.

		Zone			Soil type			Cover, frequency, density and abundance by zone												By total area			
								Cover			Frequency			Abundance			Density						
Local name	Latin name	A	B	C	Clayey	Sandy	Loamy	A	B	C	A	B	C	A	B	C	A	B	C	Cover	Frequency	Abundance	Density
Sunut	*A. nilotica* ^	+	-	-	-	-	+	2.8	-	-	18.1	19.3	-	3.5	-	-	0.6	-	-	1.5	4.2	3.5	0.04
Sial	*A. tortillis vor raddiana*^	+	+	+	+	+	+	24. 1	5.9	23.5	90.9	0.8	41.8	5.9	1.4	4.6	5.4	0.2	1.9	19.3	24.6	4.5	1.9
Talieh	*A. seyal vor fistula**	+	-	-	+	-	+	1.6	-	-	18.1	0.7	-	2.0	-	-	0.4	-	-	0.8	4.2	2.0	0.04
Kitir	*A. mellifera*^	-	-	+	-	-	+	-	-	3.0	-	-	25.0	-	-	1.0	-	-	3.0	0.7	6.4	1.0	0.06
Hashab	*A. seyel vor sayal*^	+	-	+	-	+	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-
Haraz	*A. albida**	+	-	-	-	-	+	0.8	-	-	18.1	8.0	-	1.0	-	-	0.2	-	-	0.4	4.2	1.0	0.04
Laaot	*A. nobica**	+	+	-	+	+	+	9.8	4.2	8.2	63.6	-	16.6	3.4	0.6	4.0	2.2	0.2	0.7	8.0	25.5	3.0	0.8
Samur	*A. tortillis vor tortillis*^	-	+	+	-	+	-	-	-	-	-	4.8	-	-	-	-	-	-	-	-	-	-	-
Higlig	*Balanites aegyptiaca**	+	+	-	+	+	+	4.0	10.2	-	63.6	-	-	1.4	1.2	-	0.9	0.5	-	4.8	36.2	1.3	0.5
Sarah	*Maerua crassifolia**	-	+	-	-	+	-	-	-	-	-	2.3	-	-	-	-	-	-	-	-	-	-	-
Tundub	*Capparis deciduas*^	-	+	-	+	-	-	1.6	2.5	2.0	18.1	0.6	16.6	2.0	1.5	2.0	0.4	0.1	0.3	2.3	8.1	1.8	0.2
Sidir	*Z. spina Christi**	+	-	-	-	-	+	-	1.7	1.0	-	3.0	8.3	-	1.0	1.0	-	0.08	0.08	0.6	6.4	1.0	0.06

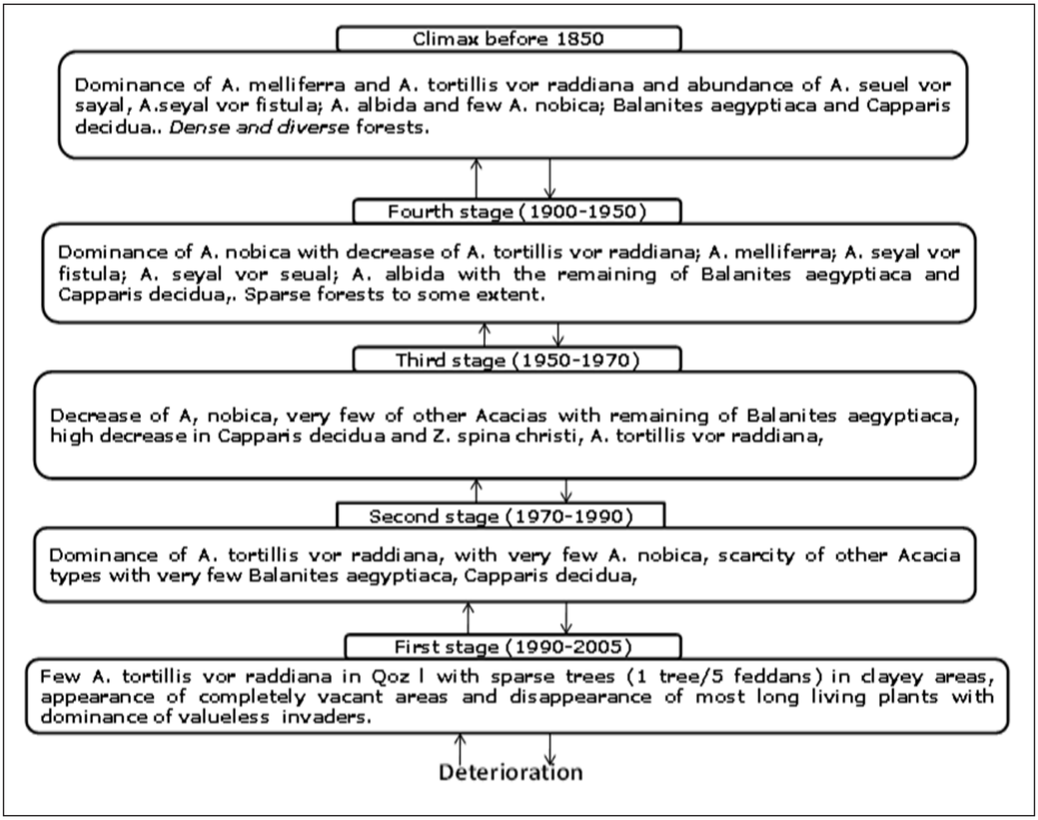
Life cycle: * Succulent, ^ non Succulent , * evergreen.

Deterioration of Acacia:

Based on studies carried out from 1928 to 1999 and the fieldwork (2005), there are four stages and a climax for Acacia in the study area (Fig.3). During the climax, prior to 1850, many abundant and diverse Acacia trees were dominating taking place as dense forests. During the fourth stage, from 1900 through 1950, A. nobica was dominating, while many other Acacia trees such as tortillis vor raddiana decreased although they were dominating during the climax and there seems to be a decrease in Acacia trees. During this stage, according to Richard (1928), Butana area was very dense with varieties of forests and abundance of Acacia mellifera; Acacia nobica; Acacia seyel vor fistula; Acacia seyel vor seyel; Acacia albidia. The dominant Acacia was Blepharis edulis which is highly nutritive to animal. Such Acacias were covering vast areas of Sufiaa, Raida Jebel Mundara and Abaytor.

Smith (1944) indicated to Acacia melifera, Acacia nobica, Acacia tortillis vor raddiana and Acacia sayel vor seyal and Capparis deciduas as dominating and they were main sources for animal feeding.

Figure (3): Acacia succession in Butana plain of eastern Sudan



During the third stage, from 1950 through 1970, still there was continuous decrease of A. nobica and other types of Acacia which became very few. Harrison (1955) mentioned that the dominant Acacia at that time was Belpharis edulis, besides abundant Acacia melifera; Maerua crassifolia, Acacia seyel vor fistula, Capparis deciduas. During 1960s, lebon (1965) indicated to the state of vegetation cover as very dense and diverse around Khartoum and Abu Delaig where Acacia tortillis vor tortillis was dominating.

During the second stage from 1970 through 1990, there was one type Acacia dominating, while there was scarcity of major other types. According to filedwork results, Acacia sharply deteriorated soon following 1970 where huge bare areas sparse trees formed the landscape. Bashar (1985) comparatively studied the statistics of Harrison (1955) and the statistics of 1985, revealed that Acacia had deteriorated in terms of density, cover and frequency following 1960. Butana became almost bare of trees where the remaining ones had confined to valleys and depressions, while Acacia mellifera occurred in plains and was replaced by Acacia nobica after being subjected to fire. Bashar (1985) further added that, trees which were replacing the old ones were unpalatable, where Calotropis procra replaced Acacia mellifera; A. seyel vor fistula and Acacia seyel vor seyel and others. Generally there is decline in Acacia by cover, frequency, abundance and density in clayey areas and dominance of low nutritive value Acacia species (Pflaubauin, 1994).

These successive stages of Acacia deterioration (Figure 3) are expressed as ecosystem carrying capacity to support Acacia in western Butana plain (Figure 4). The ecosystem carrying capacity of the study area was adequate to support Acacia up to the year 1900. Following that year, environmental changes spanning over 50 years had affected that ecosystem carrying capacity, up to 1950, by when that ecosystem carrying capacity collapsed, while Acacia continued to resist these ecological changes up to 1970. Since 1970 Acacia severely deteriorated.

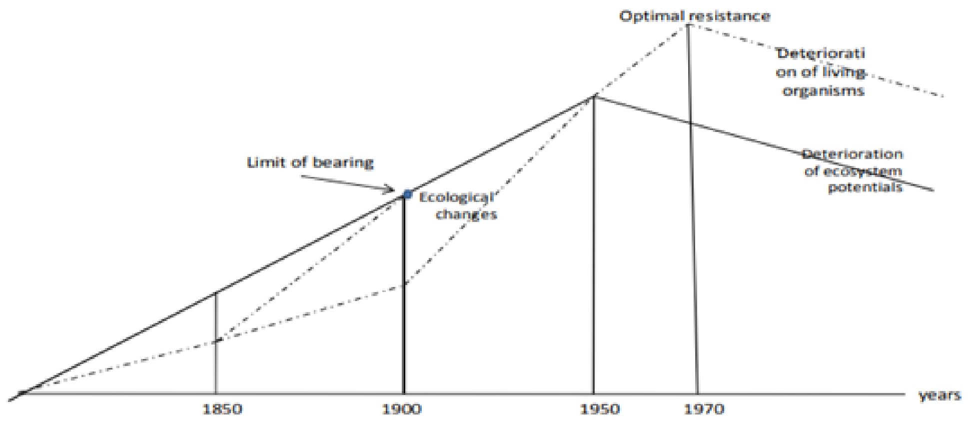


Figure 4. Ecosystem carrying capacity and Acacia resistance and deterioration.

Environmental and human factors:

Ecological disequilibrium started directly after 1970 (Fig. 4), manifested by deterioration of many Acacia trees and shrubs and appearance of unpalatable invaders. The physical causes included successive severe droughts, decline of rainfall and retreat of rainfall lines, changes in rates of humidity, temperature in micro and in regional climate of the study area.

High annual rain variability (ca.35%) and the very high evaporation rate, ca. 3mm per day in the dry season (Farouk et al, 1982). Rainfall in some major stations during 1994 recorded 777mm. in Gedarief, 669.5mm in WD el Houri and 616 mm. in Gedambalia while it was 600 mm in Hawata (Meteorology Office-Gedarief, 1994). The rainfall seasonality index (SI), precipitation concentration index (PCI) and modified Fournier index (MFI) for rainfall erosivity have been calculated and analysed in this study for the hyper-arid region of Sudan consisting of monthly rainfall measurements spanning over 60 years for three index meteorological stations, two on the Nile corridor and one on the Red Sea coast. The region is characterized by high year-to-year variability in rainfall leading to extreme seasonality/irregular distribution of rainfall over the year. Although prevalent diminishing rainfall amounts have been witnessed, there are marked tendencies for some months to become wetter, indicating changing intra-annual rainfall variability and thus monthly rainfall erosivity. No statistically significant trends were observed in rainfall seasonality and concentration during the common data period of 1945-2007. Cases of high and very high erosion powers were detected. A significant decreasing trend in erosivity is shown for one inland station (Elagib, N.A. 2010). According to Hulme (1990) rainfall depletion has been most severe in semi-arid central Sudan where between 1921-50 and 1956-85 annual rainfall has declined by 15 per cent, the length of the wet season has contracted by three weeks, and rainfall zones have migrated southwards by between 50 km and 100 km. This depletion has been due more to a reduction in the frequency of rain events rather than to a reduced rainfall yield per rain event. Ayoub (1999) compared long-term rainfall in four sub regions in Sudan and showed that rainfall decline had been in the magnitude of 30-40 per cent. The western parts of the Sudan (Kordofan and Darfur) experienced extreme rainfall anomalies than the eastern and central parts (Gedarief and Damazin), and had suffered greater periods of desiccation than the eastern and central parts. The decadal rainfall means showed below average rainfall for the last three decades in all these sub regions. Hulme et al (1989) assessed the role of an upper troposphere synoptic feature of importance in modulating surface rainfall over Sudan in the eastern Sahel: the Tropical easterly Jet (TEJ). The TEJ provides an example of an inter-regional circulation feature linking the Sahelian and Southeast Asian monsoons and ultimately, perhaps, forced by ENSO-related anomalies (Figure 5). At the same time a period of severe drought led to large-scale environmental degradation, population displacement and urbanization. In Darfur, the areas of the Fur, Birgid, Berti and Daju tribes then became targets for waves of displaced groups from Northern Darfur (Ayoub, 2006).

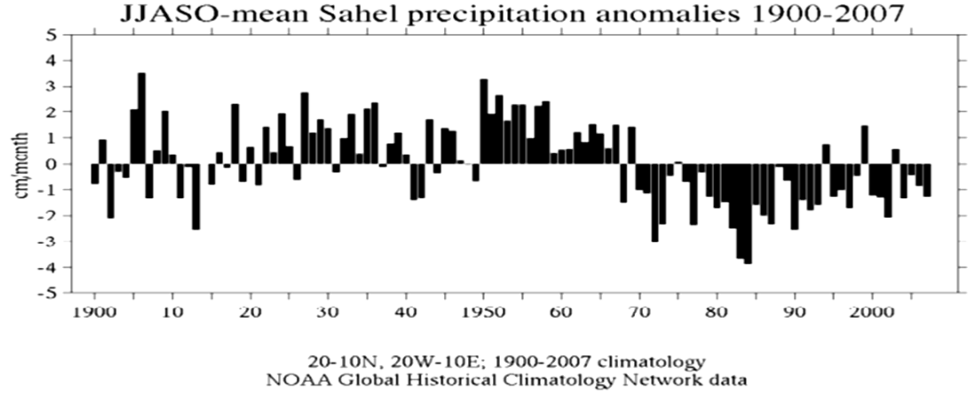


Figure 5. Precipitation anomalies in the Sahel, 1900 to 2007. Source: Stewart (2009).

Drought is one of the causes of conflict. Many areas affected by drought are arid and semi-arid areas. Under normal circumstances, these areas are low in resources and under substantial ecological pressure. When drought occurs in such arid and semi arid areas, the living conditions of local people become very difficult. In these conditions, the land yields no crops and water is insufficient for human consumption as well. People compete for the meager available resources. Pastoral communities depend on their livestock and move from place to place to look for usable pasture land and water. During drought, their movement increases. Sometimes, different pastoral groups move to the same place and want to use the same scarce resources, which cause conflicts between the two communities. There is a history of pastoral communities fighting for scarce resources in southern parts of Ethiopia, Northern Kenya, parts of Somalia and the Sudan (Mekonnen, 2006).

Soil changes in chemical and physical properties, appearance of compact salty soils, ultra alkaline and weakness of organic matter and increase in Na rate. Ph (8-8.5 more alkaline), E.C at depth of 0-45 cm was 0-1.1; at depth of 45-90 was 0-1 millimoze. Carbon organic was very low, increase in Calcium (Zubeir, 1999). Changes in topography , its distraction, increase of dust storms, damping of valleys and depressions, villages and water reservoirs, destruction of wild life and its migration to more rich and protected areas.

Fieldwork results revealed that in 1993, population of Butana was 1076430 with 50,8 density and so many villages, the area is congested by population. Average family size is 6,6 but different in age structure: 70% (5-10), 21.2% (less than 5 persons), 8.8% (more than 10). Population annual growth is 2.23% while birth rate is 37.7% in sex-age population structure; migration is 21% of the studies population, age structure: Children (less than 15 yrs=50.2%); adults (44%), elders (5.5%) while females are 46.3% and males 53.7%.

Fuel wood contributes by 40% for deterioration of Acacia in the study area according to our fieldwork survey. A family of 7 persons living close to the Blue Nile consumes on average, 8 pounds/day of fuel wood whereas weight of a tree is estimated b y75 pounds which means that a family consumes 3.3 tree/month or 40 trees /year. A family living remote from the Blue Nile with same average persons where the weight of a tree is 50 pounds, consume half a tree per day (15/month and 180/yr.), particularly A. mellifera; A. nilotica and A. seyal vor fistula. Stebbing (1954) mentioned that Rufa'a are supplement Khartoum by 1000 ton/year in 1936 and increased to 5000 ton/yr in 1956 of A. mellifera; A. nilotica and A. seyal vor fistula. Concerning agricultural expansion, fieldwork survey revealed that it contributes by 30%. Agriculture started since 1940s and diverted people from grazing to agriculture when rainfall were abundant and high production created a competition among people, increasing of agricultural land far beyond farmers affordability to cultivate (more than 20 feddans/person) all of which have cleared up Acacia (Abu Sin, 1970). Grazing contributes by 20% where for fences people use dense branches trees and thorns such as A. mellifera and Z. spina Christi where these fences are renewed annually. Also such Acacia trees are used to fill forage gab during summer by grazing Acacia branches and fruits, leaves and logging, in addition to grazing of small shrubs which stopped its growth because animal graze new soft branches and offshoots. Building purposes and folk crafts contribute by 7% where till the beginning of 1970s people used to depend on tree for building purposes and folk crafts such as Tamarix tenx (Athal). For folk crafts and agricultural tools (1%), they used stems of trees which contributed by 3%.

The eco-system in the study area tends towards deterioration (figures 3 and 4) and this can be determined by taking the variables of population (represented by overpressure) and resources (represented by eco system potentials according to Acacia utilization). It is noticed that there is clear difference in points of equilibrium, change and replacement according to Acacia utilization and the increased pressure over other resources.

Discussion:

Disturbances can include grazing, and logging. Ecologists have traditionally defined Acacia communities based on climax Acacia. Climatic variability has an impact on the Acacia dynamics.

Continued development of fully coupled climate-Acacia models will facilitate the exploration of a broad range of global change issues, including the potential role of Acacia feedbacks within the climate system, and the impact of climate variability and transient climate change on the terrestrial biosphere (Jonathan et al., 1998). As Acacia communities change, so will the associated micro-organism, fungus and animal species. Joaquín, et al., (2000) explored the validity of three responses of Acacia to increased soil erosion: reduction of Acacia cover, number of species and reduced substitution of species in the intensely eroded Eocene marls of the Prepyrenees (NE Spain). Acacia degradation explained 48% of the species number variance. In the later stages of degradation a significant substitution of species was not observed, only a lower frequency of occurrence of several species that appeared in the whole set of relevés. Through the process of degradation, 47% of species displayed significantly reduced frequencies as degradation increased; none showed a significant increase in frequency. It is concluded that there are no characteristic species in these Acacia communities that survive in the severely eroded marls. Among the few species that had increased in frequency, most only colonised favourable micro-environments (Joaquín, et al., 2000).

Conclusions:

1. Secondary succession is the series of community changes which take place on a previously colonized, but disturbed or damaged habitat such as that after felling trees in woodland, land clearance or a fire
2. Very decline of trees dominating in the past where most of Acacia trees, except of A. tortillis vor raddiana by 19.3% cover because it grows on snady soil and A. nobica by 8% cover while the remaing do not exceed 2% by cover percent and trees mixing with them we find the highest percent recorded by Balanites aegyptiaca and does not exceed 4.8% of total Acacia cover .
3. Scarcity of some trees where were extending in the past and recording zero in cover such as A. seyal vor seyel, A. tortillis vor tortillis; Maerua crassifolia and others.
4. Scarcity of long living grasses and herbs extending in the past such as I. oblongifolia, Cymbopogon proximus; Cymbogogen nervatus and Desmestachya cynosuroidea which are nutritive to human.
5. Deterioration of quantitative and qualitative structure of valuable grazing grasses and herbs Schoenefeldia gracilis; Blepharis edulis; Aristida spp; Ipomea cardoiospelala; Urocboa trichopus; Arianthema pentanda; Tephrosia spp; Penniseetum pdystachyum; Euphorbia aegyptiaca and Limeum viscosum.
6. There are obvious changes in physiologica appearance concerned with size and shape of a tree, leaves, fruits, (liha), and slow growth and so on.
7. Appearance of new intruding and invading Acacias capable for competition and extension with low nutritive value for animals such as Cassina senna; by 36% cover; Guiera senegalensis by 19.6& and B. marrubifolia which represent the highest percent in percent of Acacia cover.

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Vegetation dynamic in western Butana plain, Sudan

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Vegetation dynamic in western Butana plain, Sudan(*)

Ecological succession is the gradual process by which ecosystems change and develop over time where habitats are constantly changing, always determined by the physical parameters of the environment. As ecosystems age, the kinds of organisms found in them changes until some stable type of community forms. Initial stages are characterized by high rate of replacement and unstable and prone to erosion and wind damage. Later stages are characterized by low rate of community change and are more stable.

Plant succession is a series of predictable changes over time in the kinds of plants growing in an area. Two main types of primary and secondary succession are identified. Primary succession is the series of community changes which occur on an entirely new habitat which has never been colonized before such as a newly quarried rock face or sand dunes. The plant communities will generally change as the soil develops. Secondary succession is the series of community changes which take place on a previously colonized, but disturbed or damaged

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habitat such as that after felling trees in woodland, land clearance or a fire. The relatively stable community at the end of succession is called a climax community which is thought to be in equilibrium with the environment. The plants that initially invade sites are considered pioneer species. These species recolonize the area and essentially prepare it for the invasion of later successional species..

Succession takes place because through the processes of living, growing and reproducing, organisms interact with and affect the environment within an area, gradually changing it. Each species is adapted to thrive and compete best against other species under a very specific set of environmental conditions. If these conditions change, then the existing species will be outcompeted by a different set of species which are better adapted to the new conditions. Different stages in a particular habitat succession can usually be accurately predicted. These stages, characterised by the presence of different communities, are known as 'seres'. Succession will not go any further than the climax community which does not however, imply that there will be no further change.

The climax vegetation of an area is that which will competate other species over time and eventually dominate a site for a prolonged period, perhaps several hundred years or more, barring any new disturbance. Since one stage of succession follows another, the biomass of the plant community increases. This is the outcome of the increasing amount of net productivity — calories stored by the plant community. This, in turn, provides calories for a larger community of consumers. As succession continues, the diversity of species in the community increases at least for a time. When the system approaches its climax, the rate of increase in net productivity of the plants is consumed by its own heterotrophs. The system comes into equilibrium and reaches peak efficiency at channeling the energy of the sun into the food web of the community. The actual species involved in a succession in a particular area are controlled by geology and history of the area, the climate, microclimate, weather, soil type and other environmental factors and would be quite different from place to another although the processes involved would be the same. Succession occurs on many different timescales, ranging from a few days to hundreds of years (Off well Woodland & Wildlife Trust, 2000).

Numerous studies have underscored the importance of terrestrial ecosystems as an integral component of the Earth's climate system (Jonathan et al., 1998). This realization has already led to efforts to link simple equilibrium vegetation models with Atmospheric General Circulation Models through iterative coupling procedures. This method allows determining whether the earth is an endoergic system, i.e. the spatial sensitivity of the vegetation dynamics for climate variability the same is the temporal sensitivity (Roerink, et al., 2002).

The decrease of mean air temperature with elevation appears to be in close correlation with the general decrease of species□ richness with elevation (Grabherr et al., 1995; Schlüssel, 1999). Mean air temperature is also a determining factor for the water chemistry (e.g., pH) of remote alpine lakes. Aquatic ecosystems at high altitude might respond with extreme sensitivity to climate warming (Sommaruga-Wögrath et al., 1997; Sommaruga, 1999) and global change in general. The following parameters should be taken into account when assessing the ecological impact of climate change in the Alps, mean air temperature decreases regularly as elevation increases, at a mean rate of about 0.558 K per 100 m difference, precipitation (water + snow) tends to increase as elevation increases, with different local and regional patterns . The regular decrease of mean air temperature determines vegetation belts which are altitudinal sections characterized by a given vegetation and a given climate, i.e., bioclimatic zones, vegetation belts have an altitudinal extension of approximately 700 m and, conventionally, they are named, from bottom to top, colline, montane, subalpine, alpine and nival belts. Vegetation belts being determined by climate; their elevation varies according to variations of the mesoclimate within a range. The subalpine belt is the upper forest belt; it corresponds mainly to coniferous forests. Its lower, respectively higher limit can vary from

1200–1300 m to 1900–2000 m asl. in the northern, colder and wetter Alps, to 1600–1700 m to 2300–2400 m asl. in the internal, warmer and drier Alps.

Precipitation regimes determine oceanity or continentality, which in turn influence plant distribution (Eggenberg, 1995; Zimmermann, 1996; Kienast et al., 1998; Pache et al., 1996). Frequency of extreme climatic events such as late frosts and avalanches are important factors determining timberline position. Timberline is very likely growth-determined, with a lower thermal threshold defined by seasonal values of mean air temperature between 5.5 and 7.5 ◦C (Körner, 1998, 1999). Edaphic factors can locally compensate for climatic factors; soil may induce either a positive or a negative feedback loop in the response of plant to climate change. Mean air temperature is directly linked to the plant growth season, and the sum of temperature (degree–days) influences plant phenology linearly. Winter snow cover is a key parameter for plants sensitive to frost, and for those requiring a low amount of heat for starting their development, for winter soil microbial activity and resulting carbon and nitrogen biogeo-chemical dynamics (Brooks et al., 1997; Williams et al., 1998), and for the activity of periglacial phenomena.

Data and Methods:

The study area lies at 14 – 16 N and 33 – 35 E and belongs to Gedarief state. It is bordered by the Sahara desert from the north, Rahad River (scheme) from the south, Blue Nile from the west and Ethiopian highlands from far the east. Gedarief state is located at 34-36^0 E, bordered by states of Kassala, Sinnar, Gezira and Khartoum from the north, south, west and northwest sides respectively and by the Ethiopian borders from the east (figure 2). Gedarief state has an area of 263, 75 km^2. It is part of the Butana region which is a plain surface intermitted by dispersed hills covered with alluvium. Topography of Gedarief state includes three major units. Firstly, highlands and isolated mountains in the southeast. Secondly, plain area dominating the state characterized by clayey soil (45-80% clay particles) either flat or slow sloped. Thirdly, the Wadis (valley) area that are including depositional sites around seasonal rivers, such as the Atbara and Rahad rivers. Most of the Gedarief area is underlain by Basement Complex of Tertiary Basalts both of which provide little water except in the detrital material around the occasional hills and small supplies to be found along joints in the rock (Davies, 1964) where rainfall range is 300-900m/year. Gedarief state has two distinctive climatic belts. The first one is semi arid climate found in the north and northwest and characterized by summer seasonal rains during July-October. The second one is a wet climate found in the eastern and southern parts of the state with average rainfall of 500-900 mm/ year and maximum mean temperature of 47 ^{0}C. High annual rain variability(ca.35%) and the very high evaporation rate, ca. 3mm per day in the dry season (Farouk et al, 1982). Rainfall in some major stations during 1994 recorded 777mm. in Gedarief, 669.5mm. in Wd el Houri and 616 mm. in Gedambalia while it was 600 mm. in Hawata (Meteorology Office-Gedarief,1994).

Quantitative coverage of vegetation is done by using the squares methods. The study area is divided into three main zones indicated to by A,B and C letters according to density and diversity of vegetation. Firstly, area of the squares is determined as 10000m^2 (100mx 100m). Secondly, midpoint at which the eight major and minor directions meet together is determined by the village of Um Akash. Thirdly, 5 to 7 squares for each direction line with distance interval of 2-3 km are chosen. Fourthly, square method is applied for vegetation cover which is used for by arid lands. Lastly, formulas are used to get coverage, frequency, density and abundance of plant because the Square method has been designated on the variables of number of one vegetation type, percent of vegetation cover for one type, plant height, plant frequency, abundance, density and number of plant. Type cover, frequency, density and abundance are calculated as follows:-

Cover (%) = number of one type x100/ total of plants = number %

Frequency (%) = n umber of squares for one type (A) x 100/total number of the study squares = number%

Density = number of individual of one type (A) / total number of the studies squares = number of plant/ square

Abundance = number of individual of one type (A) /number of squares where that type (A) is found

Following Walton (1979), Hills (1966) and Clarke (1954) vegetation cover in the study is classified into Succulent perennials, non-Succulent perennials, annual and ephemeral. Vegetation changes by zones are tackled by reviewing different rates for the dominant types according to cover, frequency and abundance and the comparing the results with the state of these types in the past based on previous studies and fieldwork in order to know quantitative and qualitative changes in plant structure for recent and past.

Figure 2: States of Sudan and location of the study area

Vegetation covers by zone and soil type:

Acacia is a Greek word means ''thorns'', which is a Genus for trees and shrubs and some escalading plants of Mimosaceane family. They are drought resisting. There are more than 300 type of Acacia in Australia, 1000 in America while there are more than 400 type in Africa and Asia with restricted types in arid and semi arid parts. They take place as forest mixed with other plant types such as Simaroubaceae, Capparideceae and Tamaricaceae and Rhamnaceae. This family is identical and sensitive to climate and soil factors. Therefore, they occur in forms of dense or sparse forests according to these factors, except those ones subjected to human interference.

Many types of succulent; non-succulent and evergreen perennials are found in the study area. Succulent plants store water in their stems for hard times of water deficiency while the non succulent ones extend their roots deep into the soil searching for water, and the evergreens have adapted to resisting drought. In addition, there are annual drought resisting long living and ephemeral grasses. These types of natural vegetation differ in occurrence spatially and by soil type (tables 1and2). Zone A has the highest occurrence followed by zone B and C respectively. Acacia tortillis vor raddiana and Acacia nilotica dominate areas close to the Blue Nile in zone A. They are found in forms of clustered forests such as Rufa'a, Dalawat, Hibaika and Ahamda forests. In addition there are more than 22 types of grass and herbs in this zone. Zone B lies in the middle of the study area which have been subject to extensive traditional rainfed agriculture. This type of agriculture has cleaned up majority of Acacia trees where by now there is one tree / 5 feddans (1 feddan =1.038 acres), mostly of Balanites aegyptiaca. In this zone there are 31 types of long living and ephemeral grasses. Zone C has little tree occurrence and they are mostly of Acacia mellifera beside 15 types of grass and ephemeral herbs. Differences on vegetation cover are depicted by soil types (tables 1 and 2). There is diversity in Acacia trees and long living and ephemeral grasses on the clayey soil, and although of that, trees are less occurring. On the sandy soil, tree species are more diverse and dispersive but, less denser while long living grasses and ephemerals are less diverse. On the loamy soil, Acacia nilotica are abundant with few Acacia seyel vor fistula and some other types of grasses and ephemeral herbs.

Table (1): Occurrence of trees and shrubs by zone, soil type and life cycle

local name	Latin name	zones			soil types			Classification by life cycle
		A	B	C	clay	sand	loam	
Sunut	A. nilotica	+	-	-	-	-	+	always non-Succulent perennials
Sial	A. tortillis vor raddiana	+	+	+	+	+	+	always non-Succulent perennials
Talieh	A. seyal vor fistula	+	-	-	+	-	+	always non-Succulent perennials
Kitir	A. mellifera	-	-	+	-	-	+	always non-Succulent perennials
Hashab	A. seyel vor sayal	+	-	+	-	+	-	always non-Succulent perennials
Haraz	A. albida	+	-	-	-	-	+	always Succulent perennials
Laaot	A. nobica	+	+	-	+	+	+	always Succulent perennials
Samur	A. tortillis vor tortillis	-	+	+	-	+	-	always non-Succulent perennials
Higlig	Balanites aegyptiaca	+	+	-	+	+	+	evergreen
Sarah	Maerua crassifolia	-	+	-	-	+	-	always non-Succulent perennials
Tundub	Capparis deciduas	-	+	-	+	-	-	always non-Succulent perennials
Sidir	Z. spina Christi	+	-	-	-	-	+	evergreen
Oushar	Calo tropis procera	+	-	-	+	-	+	evergreen

Dahsir	I. oblongifolia	+	-	+	-	-	+	evergreen
Senameca	Cassia senna	+	+	-	+	+	+	perennial long living
Hanzal	Citrullus colocynthis	+	-	+	-	+	-	annual
Shwaika	Guiera sengalinsis	+	+	+	+	+	+	annual
Irig Agrab	Clitoria tematea	-	+	+	-	-	+	evergreen
Gudaim	Geruria tanar	-	+	-	-	+	-	always non Succulent perennials

Table (2): Occurrence of grasses and ephemerals by zone, soil type and life cycle

local name	Latin name	zones			soil types			classification by life cycle
		A	B	C	clay	sandy	loam	
Dambalab	Schoenefeldia gracilis	+	-	+	-	-	+	quickly disappearing
Maharaib	Cymbopogon proximus	-	-	+	-	+	-	long living
Huntout	Ipomea cardoiospelala	+	-	+	+	-	+	quickly disappearing
Safra	Tephrosia spp	+	+	-	+	+	-	quickly disappearing
Gao	Aristida spp	-	+	-	-	+	-	quickly disappearing
Tibir	Ipomea cordofana	+	-	+	+	-	+	quickly disappearing
Dhuraisa	Tribulus terrestris	+	+	+	+	+	+	quickly disappearing
Gibain	Solamum aethiopicum	-	+	-	+	-	-	quickly disappearing
Buda	Striga hermothica	+	+	+	+	+	+	quickly disappearing
Turba	Limeum viscosum	+	+	-	+	-	-	quickly disappearing
Nal	Cymbopogon nervatus	-	-	+	+	+	-	long living
Saad	Cyperus compacutus	+	-	+	+	-	+	quickly disappearing

Bous	Dipterygium glaucum	-	-	+	+	+	-	long living
Suraib	T. emeroides	+	-	+	+	+	-	quickly disappearing
Anies	S. purpureo sericeum	+	-	-	+	+	-	quickly disappearing
Saha	Blepharis edulis	-	-	+	+	-	-	quickly disappearing
Rabaa	Arianthema pentanda	+	+	-	+	-	+	quickly disappearing
Khadra baryia	Corchorus olitorius	+	+	+	+	-	+	quickly disappearing
Umlaban	Euphorbia aegyptiaca	+	+	+	+	-	+	quickly disappearing
Umginaigra	Penniseetum pdystachyum	+	-	-	+	+	+	quickly disappearing
Mulaita	Picridium tingitanum	+	+	-	+	-	+	quickly disappearing
Fagous	Cucumis melo	-	+	-	+	-	+	quickly disappearing
Huskaniet	Cenchrus catharticus	+	+	-	+	-	+	long living
Fakha	Achyranthes aspera	-	+	-	+	-	-	quickly disappearing
Rihan	Ocimum basilicum	-	+	-	+	-	+	quickly disappearing
Tamalaika	Gunandropsis gynandra	+	-	-	+	-	+	quickly disappearing
Umasabi	Dactylocternium aegyption	+	-	-	+	-	+	long living
Umgalagil	Aristolochia bractteata	+	-	-	+	-	-	quickly disappearing
Sharaia	I. Semitrijuge	-	+	-	+	-	-	quickly disappearing
Dafra	Echino chillia coloruain	+	+	-	+	-	+	quickly disappearing
Waika baria	Hibiscus aescalentus	+	+	+	+	-	+	quickly disappearing
Ummaliha	Dinebra arabica	+	+	-	+	-	+	quickly disappearing
Halfa	Desmestachya cynosuroidea	+	-	-	+	-	-	long living
KhadraeBagar	B. marrubifolia	-	+	-	+	-	+	long living
Adar	Sorghum spp	+	-	+	+	-	+	long living
Tifa	Urocboa trichopus	-	+	-	+	-	-	quickly disappearing

Vegetation change:

Table (3) depicts cover; frequency; abundance and density of vegetation cover in the study area. Although these statistics are low in zone A, excepting forests close to the Blue Nile, they are the highest compared to the other two zones. In zone A, Acacia tortillis vor raddiana ranked high by 24.1% cover, 90.9% frequency, 5,9 plant abundance and 5.4 plant density. Figure (2) and fieldwork indicated that tree species dominated in the past were not only Acacia tortillis vor raddiana, but were Acacia nobica (9.8% by now); Acacia albida (8%), Balanites aegyptiaca (4%) while all of Acacia seuel vor seyal; Maerua crassifolia; Acacia tortillis vor tortillis; Acacia seyel vor fistula are representing 1.6 % by now and I. oblongifolia disappeared completely. As for long living grass, Cassia senna comes first with 24% cover, 100% frequency, 7.5 abundance and 7.5 density, followed by Guiera senegalensis while the remaining other types do not represent more than 5% cover whereas the majority are new intruders plants. Changes also occurred into plant distribution by soil type. On the clayey soil, many grasses became rare by type and few by quantity such as Desmestachya cynosuroidea; Schoenefeldia gracilis and Aristida spp T. emeroides; Dipterygium glaucum; Tephrosia spp and Sorghum spp. On sand dunes some types disappeared such as Schoenefeldia gracilis and Cymbopogon nervatus although they used to dominate this zone.

Table (3): Statistics of cover; frequency; abundance and density of trees and shrubs by zone and total

local name	Latin name	By zones												By total area			
		Cover (%)			Frequency (%)			abundance (type/ a square)			density (type/ a square			cover	frequency	abundance	density
		A	B	C	A	1.5	C	A	B	C	A	B	C				
Sunut	A. nilotica	2.8	-	-	18.1	19.3	-	3.5	-	-	0.6	-	-	1.5	4.2	3.5	0.04
Sial	A. tortillis vor raddi-ana	24. 1	5.9	23.5	90.9	0.8	41.8	5.9	1.4	4.6	5.4	0.2	1.9	19.3	24.6	4.5	1.9
Talieh	A. seyal vor fis-tula	1.6	-	-	18.1	0.7	-	2.0	-	-	0.4	-	-	0.8	4.2	2.0	0.04
Kitir	A. mellif-era	-	-	3.0	-	-	25.0	-	-	1.0	-	-	3.0	0.7	6.4	1.0	0.06
Hashab	A. seyel vor sayal	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-
Haraz	A. albida	0.8	-	-	18.1	8.0	-	1.0	-	-	0.2	-	-	0.4	4.2	1.0	0.04
Laaot	A. nobica	9.8	4.2	8.2	63.6	-	16.6	3.4	0.6	4.0	2.2	0.2	0.7	8.0	25.5	3.0	0.8
Samur	A. tortillis vor tor-tillis	-	-	-	-	4.8	-	-	-	-	-	-	-	-	-	-	-
Higlig	Balanites aegypti-aca	4.0	10.2	-	63.6	-	-	1.4	1.2	-	0.9	0.5	-	4.8	36.2	1.3	0.5
Sarah	Maerua crassi-folia	-	-	-	-	2.3	-	-	-	-	-	-	-	-	-	-	-
Tundub	Capparis deciduas	1.6	2.5	2.0	18.1	0.6	16.6	2.0	1.5	2.0	0.4	0.1	0.3	2.3	8.1	1.8	0.2
Sidir	Z. spina Christi	-	1.7	1.0	-	3.0	8.3	-	1.0	1.0	-	0.08	0.08	0.6	6.4	1.0	0.06
Oushar	Calo tropis procera	2.0	-	9.2	27.2	-	25.0	1.6	-	3.0	0.5	-	0.8	3.0	51.6	2.8	0.3
Dahsir	I.oblongi-folia	-	-	-	-	36.0	-	-	-	-	-	-	-	-	-	-	-
Sen-ameca	Cassia senna	34.0	47.5	27.5	100	3.0	66.6	7.5	3.7	3.4	7.5	3.2	2.3	36.0	72.3	4.8	3.5
Hanzal	Citrullus colocyn-this	2.0	2.5	6.1	18.1	19.6	6.6	2.5	1.5	3.0	0.5	0.1	0.5	3.0	12.8	2.3	0.3
Shwaika	Guiera senga-linsis	13.5	22.0	21.4	90.9	3.6	41.6	3.3	2.6	4.2	3.0	1.0	1.8	19.6	53.2	3.2	1.7
Irig Agrab	Clitoria tematea	3.3	3.4	-	18.1	12.5	-	2.6	1.3	-	0.7	0.2	-	3.6	12.8	2.0	0.3

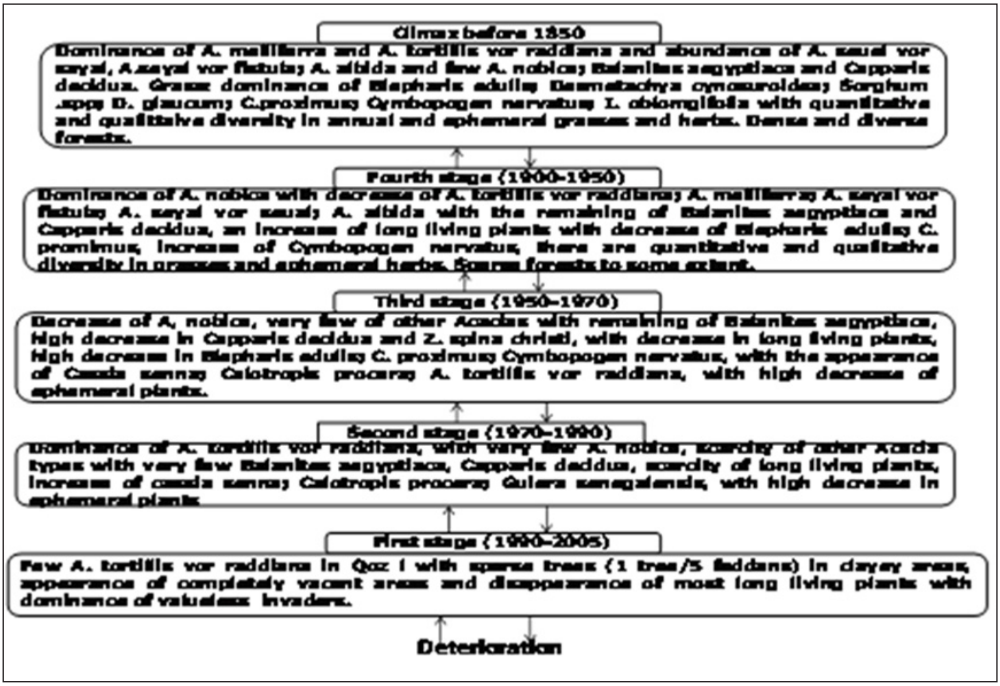
Zone B is dominant by Balanites aegyptiaca and A. tortillis vor raddiana, while remaining Acacia trees did represent more than 5% covering. A. tortillis vor raddiana and Balanites aegyptiaca; Z. spina Christi, A. seyel vor sayal; A. seyel vor sayal; Maerua crassifolia; A. nobica and Capparis deciduas are very rare while they were dominant in the past. Intruding grasses such as Cassina senna and Guiera senegalensis are dominating. This changed grass and herbal quantity and occurrence by soil type. Plant species dominating clayey soil included Schoenefeldia gracilis; Gunandropsis gynandra; Arianthema pentanda; Dipterygium glaucum; I. Semitrijuge and Sorghum spp. On sandy soil, Schoenefeldia gracilis; Cymbopogon nervatus are very rare and there is few Citrusullous colocynthis.

In zone c, vegetative cover sharply decreasing where Tortillis vor raddiana dominates sandy soil by 23% cover, 41.3% frequency, 4.6 abundance and density by 1.9. It is followed by A. nobica with 8.2% cover, 16.6 % frequency, 4 abundance and 0.7 densities. This zone had experienced A. mellifera which formed forests in the past and by now representing 3% of the total vegetation cover. A. seyal vor seyel; A. albida and A. seyel vor fistula have disappeared. Grasses such as Z. Spina Christi does not exceed 1% and also Capparis deciduas which were used to cover vast areas in this zone in the past. There are new intruders and invaders representing high percent such as Cassina senna by 27.5% cover; Guiera senegalensis by 9.2% and Citrullous colocynthis by 6.1% of cover. Also Blepharis edulis; Arianthema pentandra; Cymbopogen nervatus and Pennisetum pdystachyum have deeply deteriorated.

Plant succession:

Based on studies carried out from 1928 to 1992 and the fieldwork (2005), there are four stages and a climax for plant succession in the study area (Fig.2).

Figure (2): Plant succession in Butana plain of eastern Sudan



During the climax, prior to 1850, many Acacia trees are dominating with abundance and diversity forming dense forests. Similarly, many long living annual grasses and ephemerals are dominating. During the fourth stage of 1900-1950, A. nobica dominated while many other Acacia trees such as tortillis vor raddiana decreased although they were dominating during climax. There is increase in long living grass with fluctuating increase and decrease in diversity and quantity of some species. There seems to be a decrease in trees and increases in grass. According to Richard (1928) Butana area was very dense with varieties of forest area and abundance of Acacia mellifera; Acacia nobica; Acacia seyel vor fistula; Acacia seyel vor seyel; Acacia albidia. The dominant plant was Blepharis edulis which is highly nutritive to animals. Such plants were covering vast areas of Sufiaa, Raida Jebel Mundara and Abaytor. Davis (1939) indicated that Butana is well known with extending pastures of grasses varieties such as Blepharis edulis, Schoenefeldia gracilis. Smith (1944) indicated to Acacia melifera, Acacia nobica, Acacia tortillis vor raddiana and Acacia sayel vor seyal and Capparis deciduas as dominating and they were main sources for animal feeding.

During the third stage, from 1950- to 1970, still there is continuous decrease of A. nobica and there were few Acacia and still there is decrease in some other types. Long living grasses started to decrease, appearance of new plant invaders and high decrease in ephemerals. Harrison (1955) mentioned that the dominant plant at that time was Belpharis edulis, besibes abundant Acacia melifera; Maerua crassifolia, Acacia seyel vor fistula, Capparis deciduas and many grasses of Aristda spp, Schoenefelida gracilis, Sorghum sp., Cymbopogon proxmus, I. Semitrijuge, Echino chillia coloruain, Gunandropsis gynandra and others. Warrel (1959) indicated to Aristida spp, Schoenefelida gracilis, Cymbopogen nervatus as the dominant plants. During 1960s, lebon (1965) indicated to Blepharis edulis as few although it was dominating during 1950s and was at its end in the mid of very dense grasses such as Cymbopogen nervatus, Sorghum spp, Dipteryguim glaucum and Cymbopogon proximus and others. In addition, the state of vegetative cover was very dense and diverse around Khartoum and Abu Delaig where Acacia tortillis vor tortillis was dominating.

During the second stage (1970-1990), one type Acacia was dominating while there is scarcity of major other types. Similarly, there is scarcity of long living grass and increasing of invaders and sharp decrease in ephemerals. According to filedwork results, natural vegetation sharply changed after 1970 where huge areas became bare and some others have only sparse trees. Grasses and herbs started to deteriorate and disappear. Barral (1977) (according to EL Hassan, 1981) revealed that Schoenefeldia gracilis which had succeeded Belpharis eduulis represented only 10% in 1980, while it was representing 20% in 1966. Belpharis eduulis represented 70% in 1955, while now represented only 10%. Bashar (1985) comparatively studied the statistics of Harrison (1955) and the statistics of 1985 and confirmed that vegetative cover has deteriorated in terms of density, cover, frequency after 1960. He indicated that Butana was almost bare of trees and the majority concentrated in valleys and depressions, while Acacia mellifera occurred in plains and was replaced by Acacia nobica after being subjected to fire. Bashar (1985) further added that, trees which were replacing the old ones were unpalatable. Calotropis procra replaced Acacia mellifera; A. seyel vor fistula and Acacia seyel vor seyel and others. non palatable grass species started to appear since 1984 and there is decrease in the percent of Schoenefelida gracilis; Aristida sp. and Cymbopogen nervatus (Gunied and Pflaubauin, 1992).

Generally there is decline in plant cover, frequency, abundance and density in clayey areas, disappearance of most long living and ephemerals, dominance of low nutritive value plant species; changes in grass structure (Gunied and Pflaubauin, 1992).

Stage of ecological system disorder clearly started after 1970 and characterized by:

– Disappearance of trees and shrubs used to be in the past with the occurrence of radical changes in ecological structure and disappearance of palatable plant species for human and animal and appearance of plant invaders.

– Occurrence of successive acute droughts, decline of rainfall and retreat of rainfall lines, changes in rates of humidity, temperature in micro and regional climate.

– Soil changes in chemical and physical properties, appearance of compact salty soils, ultra alkaline and weakness of organic matter and increase in Na rate.

– Changes in topography, its distraction, increase of dust storms, damping of valleys and depressions, villages and water reservoirs.

– Destruction of wild life and its migration to more rich and protected areas.

- The pH tends towards alkalinity (7-8.8)
- E.C. is normal (0-1.0 millimoze in depth of 0-45 cm.m 45-90cm).
- The eco-system in the study area tends towards deterioration (figures 3 and 4)

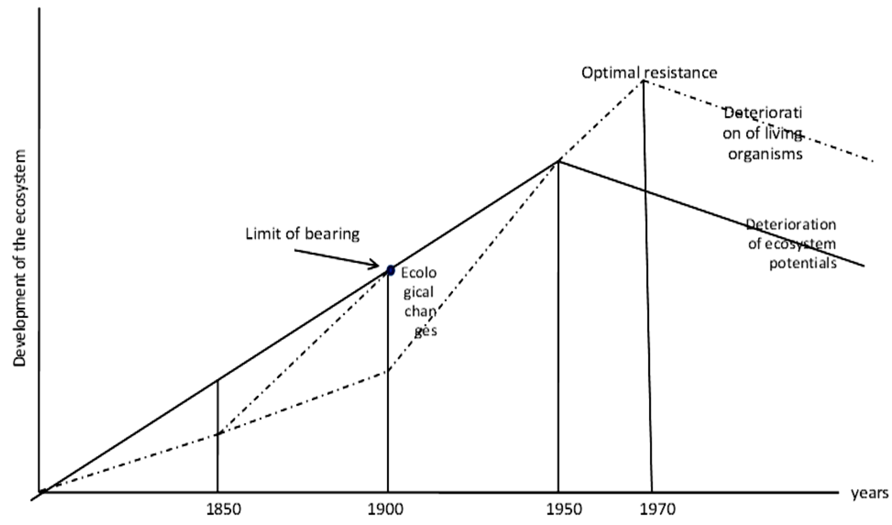


Figure (3): stages of development of the ecosystem in Butana plain between 1850 through 1999

Source (Fieldwork, 2005)

Discussion:

It is worth remembering that as plant communities change, so will the associated micro-organism, fungus and animal species. Succession involves the whole community, not just the plants. Change in the plant species present in an area is one of the driving forces behind changes in animal species. This is because each plant species will have associated animal species which feed on it. The presence of these herbivore species will then dictate which particular carnivores are present. The structure or 'architecture' of the plant communities will also influence the animal species which can live in the microhabitats provided by the plants. Changes in plant species also alter the fungal species present because many fungi are associated with particular plants.

4. Climax in some Maryland habitats is a hardwood forest, in some California habitats is grassland, and in some Arizona habitats is a desert D. In characterizing succession, we only list the dominant plants (the ones that shape the ecosystem)

This study explored the validity of three responses of vegetation to increased soil erosion: reduction of vegetation cover, number of species and reduced substitution of species. 201 relevés, including edaphic and geomorphological data, were surveyed in the intensely eroded Eocene marls of the Prepyrenees (NE Spain). Changes in plant species' presence in relevés from different degradation stages were compared. The level of vegetation degradation was defined as the total phanerogam cover which, in the studied area, was correlated to the degree of soil erosion. The considered trends were validated. Reduction of phanerogam cover and species number were gradual from low to high-eroded areas. Vegetation degradation explained 48% of the species number variance. In the later stages of degradation a significant substitution of species was not observed, only a lower frequency of occurrence of several species that appeared in the whole set of relevés. Through the process of degradation, 47% of species displayed significantly reduced frequencies as degradation increased; none showed a significant increase in frequency. It is concluded that there are no characteristic species in these plant communities that survive in the severely eroded marls. Among the few species that had increased in frequency, most only colonised favourable micro-environments (Joaquín, et al., 2000).

A late Miocene paludal to lacustrine sequence from a carbonate basin in NW Bulgaria (Staniantsi Basin) is analysed displaying up to 27 rhythmically bedded sedimentary cycles. In the lower part of the sequence, the cycles consist of alternating autochthonous brown coal and marls containing diverse mollusc assemblages. The upper part of the sequence is characterized by alternating dark to light grey clays and calcareous silts. A palynomorph record comprising 163 samples is analysed by statistical means to reconstruct vegetation changes. The Coexistence Approach is used to calculate quantitative palaeoclimate records for 6 parameters. The studied section displays hierarchical cyclicity patterns. Longer-term cycles possibly related to eccentricity (period ~100 kyr) are present in the palynomorph record and show climate changes of warmer/wetter and cooler/drier periods in combination with frequency oscillations of thermophilous elements. Short-term cycles most probably related to precession (period ~21.7 kyr) are expressed by alternations of brown coal and marl/shell beds and show cyclic change in peat-forming vegetation related to oscillations of the groundwater level. As a triggering mechanism, wetter/warmer and drier/cooler climate phases related to orbital precession are probable. In addition, sections sampled at high resolution display small scale climate and vegetational variability. As is shown by the analysis ferns were an important component of the peat-forming vegetation, while outside the mire, wetland vegetation consisting of pioneers and a mixed mesophytic forest with evergreen shrubs existed. An oligo- to mesotrophic slightly alkaline lake became repeatedly established with a diverse mollusc fauna and dense hydrophytic vegetation with characean meadows. In the upper part of the section, a spreading of herbaceous vegetation is observed, also known from other contemporaneaous palynomorph records in Bulgaria and surrounding areas. The increase of Asteraceae in the upper part of the section, combined with a marked decrease in woody taxa, points to an opening of habitats and a decrease in mean annual precipitation. This trend is paralleled by the mollusc fauna which yields several terrestrial, partly xerophilous taxa (Utescher, 2009). The late Paleozoic deglaciation is the vegetated Earth's only recorded icehouse-to-greenhouse transition, yet the climate dynamics remain enigmatic. By using the stable isotopic compositions of soil-formed minerals, fossil-plant matter, and shallow-water brachiopods, we estimated atmospheric partial pressure of carbon dioxide (pCO_2) and tropical marine surface temperatures during this climate transition. Comparison to southern

Gondwanan glacial records documents covariance between inferred shifts in pCO_2, temperature, and ice volume consistent with greenhouse gas forcing of climate. Major restructuring of paleotropical flora in western Euramerica occurred in step with climate and pCO_2 shifts, illustrating the biotic impact associated with past CO_2-forced turnover to a permanent ice-free world (Isabel, 2007).

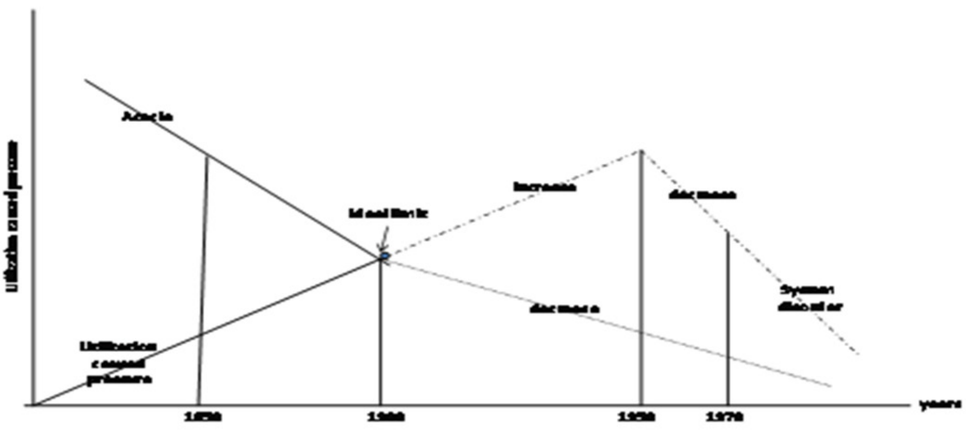


Figure (4): Reversal relationship between Acacia and pressure caused utilization

Source : Fieldwork,2005

A naturally occurring agent of change in the biotic communities of the Colorado Plateau is ecological succession. Following any disturbance, either natural or human-caused, communities undergo a somewhat orderly process of recolonization termed succession. Disturbances can include avalanches, wildfires, blowdowns, insect infestations, disease outbreaks, grazing, and logging. Ecologists have traditionally defined plant communities based on climax vegetation. Climatic variability has an impact on the vegetation dynamics is obvious. Less obvious is how to quantify these phenomena. A possible way to do this is by using long-term satellite observations; spatial and temporal changes of remotely sensed vegetation indices may reveal the vegetation dynamics in a quantitative way. Long-term meteorological data over different climatic regions will give quantitative information of climate variability. By coupling these two datasets climate impact on vegetation dynamics can be assessed. Such an approach is tested with a dataset covering Europe and part of Sahelian Africa over three years. For every year a Fourier analysis is applied to the time series of remotely sensed NDVI (Normilized Difference Vegetation Index) images to derive the mean, annual and 6-months Fourier Components (FC) amplitude and phase, which quantify the vegetation dynamics. A Climate Indicator (CI=LP/Rn) is defined as the ratio of latent heat of vaporation (L) times annual precipitation (P) over annual net radiation (Rn). The spatial relationship between CI and FC is found similar for Europe and Africa. From CI=0 till 1 the FC increases steep, whereafter it stabilises around CI=1.5 (potential evapotranspiration is reached). When CI further increases precipitation becomes a burden for the vegetation development and FC de- creases again.

Atmospheric General Circulation Model and the IBIS (version 1) Dynamic Global Vegetation Model are directly coupled through a common treatment of land surface and eco-physiological processes, which is used to calculate the energy, water, carbon, and momentum fluxes between vegetation, soils, and the atmosphere. On one side of the interface, GENESIS simulates the physics and general circulation of the atmosphere. On the other side, IBIS predicts transient changes in the vegetation structure through changes in the carbon balance and competition among plants within terrestrial ecosystems. As an initial test of this modelling framework, we perform a 30 year simulation in which the coupled model is supplied with modern CO_2 concentrations, observed ocean temperatures, and modern insolation. In this exploratory study, we run the GENESIS atmospheric model at relatively coarse horizontal resolution (4.5° latitude by 7.5° longitude) and IBIS at moderate resolution (2° latitude by 2° longitude). We initialize the models with globally uniform climatic conditions and the modern distribution of potential vegetation cover. While the simulation does not fully reach equilibrium by the end of the run, several general features of the coupled model behaviour emerge. We compare the results of the coupled model against the observed patterns of modern climate.

The model correctly simulates the basic zonal distribution of temperature and precipitation, but several important regional biases remain. In particular, there is a significant warm bias in the high northern latitudes and cooler than observed conditions over the Himalayas, central South America, and north-central Africa. In terms of precipitation, the model simulates drier than observed conditions in much of South America, equatorial Africa and Indonesia, with wetter than observed conditions in northern Africa and China. Comparing the model results against observed patterns of vegetation cover shows that the general placement of forests and grasslands is roughly captured by the model. In addition, the model simulates a roughly correct separation of evergreen and deciduous forests in the tropical, temperate and boreal zones. However, the general patterns of global vegetation cover are only approximately correct: there are still significant regional biases in the simulation. In particular, forest cover is not simulated correctly in large portions of central Canada and southern South America, and grasslands extend too far into northern Africa. These preliminary results demonstrate the feasibility of coupling climate models with fully dynamic representations of the terrestrial biosphere.

Continued development of fully coupled climate-vegetation models will facilitate the exploration of a broad range of global change issues, including the potential role of vegetation feedbacks within the climate system, and the impact of climate variability and transient climate change on the terrestrial biosphere (Jonathan et al., 1998).

Most of the Gedarief area is underlain by Basement Complex of Tertiary Basalts both of which provide little water except in the detrital material around the occasional hills and small supplies to be found along joints in the rock (Davies, 1964). Basement complex rocks prohibit well digging and they are of low porosity and permeability which allow little or no water to penetrate downwards except along temporary water streams where the upper part of these rocks is weathered for few meters and is therefore porous (Farouk et al, 1982).

The underground supplies are not only small, but those at depth are extremely hard whilst the shallower ones are saline. Most of these water sources are temporal and linking with the rainy season where rainfall range is 300-900m/year. Gedarief state has two distinctive climatic belts. The first one is semi arid climate found in the north and northwest and characterized by summer seasonal rains during July-October. The second one is a wet climate found in the eastern and southern parts of the state with average rainfall of 500-900 mm/ year and maximum mean temperature of 47 ^{0}C.

High annual rain variability (ca.35%) and the very high evaporation rate, ca. 3mm per day in the dry season (Farouk et al, 1982). Rainfall in some major stations during 1994 recorded 777mm. in Gedarief, 669.5mm in Wd el Houri and 616 mm. in Gedambalia while it was 600 mm. in Hawata (Meteorology Office-Gedarief, 1994). The rainfall seasonality index (SI), precipitation concentration index (PCI) and modified Fournier index (MFI) for rainfall erosivity have been calculated and analysed in this study for the hyper-arid region of Sudan consisting of monthly rainfall measurements spanning over 60 years for three index meteorological stations, two on the Nile corridor and one on the Red Sea coast. The region is characterized by high year-to-year variability in rainfall leading to extreme seasonality/irregular distribution of rainfall over the year. Although prevalent diminishing rainfall amounts have been witnessed, there are marked tendencies for some months to become wetter, indicating changing intra-annual rainfall variability and thus monthly rainfall erosivity. No statistically significant trends were observed in rainfall seasonality and concentration during the common data period of 1945-2007. Cases of high and very high erosion powers were detected. A significant decreasing trend in erosivity is shown for one inland station (Elagib, N.A. 2010).

According to Hulme (1990) rainfall depletion has been most severe in semi-arid central Sudan where between 1921-50 and 1956-85 annual rainfall has declined by 15 per cent, the length of the wet season has contracted by three weeks, and rainfall zones have migrated southwards by between 50 km and 100 km. This depletion has been due more to a reduction in the frequency of rain events rather than to a reduced rainfall yield per rain event. Ayoub (1999) compared long-term rainfall in four sub regions in Sudan and showed that rainfall decline had been in the magnitude of 30-40 per cent. The western parts of the Sudan (Kordofan and Darfur) experienced extreme rainfall anomalies than the eastern and central parts (Gedarief and Damazin), and had suffered greater periods of desiccation than the eastern and central parts. The decadal rainfall means showed below average rainfall for the last three decades in all these sub regions. Hulme et al (1989) assessed the role of an upper troposphere synoptic feature of importance in modulating surface rainfall over Sudan in the eastern Sahel: the Tropical easterly Jet (TEJ). The TEJ provides an example of an inter-regional circulation feature linking the Sahelian and Southeast Asian monsoons and ultimately, perhaps, forced by ENSO-related anomalies. At the same time a period of severe drought led to large-scale environmental degradation, population displacement and urbanization. In Darfur, the areas of the Fur, Birgid, Berti and Daju tribes then became targets for waves of displaced groups from Northern Darfur (Ayoub, 2006). Drought is one of the causes of conflict. Many areas affected by drought are arid and semi-arid areas. Under normal circumstances, these areas are low in resources and under substantial ecological pressure. When drought occurs in such arid and semi arid areas, the living conditions of local people become very difficult. In these conditions, the land yields no crops and water is insufficient for human consumption as well. People compete for the meager available resources. Pastoral communities depend on their livestock and move from place to place to look for usable pasture land and water. During drought, their movement increases. Sometimes, different pastoral groups move to the same place and want to use the same scarce resources, which cause conflicts between the two communities. There is a history of pastoral communities fighting for scarce resources in southern parts of Ethiopia, Northern Kenya, parts of Somalia and the Sudan (Mekonnen, 2006).

Conclusion:

1. Secondary succession is the series of community changes which take place on a previously colonized, but disturbed or damaged habitat such as that after felling trees in woodland, and land clearance by fire.

2. Very decline of trees dominating in the past where most of Acacia trees, except of A. tortillis vor raddiana by 19.3% cover because it grows on snady soil and A. nobica by 8% cover while the remaing do not exceed 2% by cover percent and trees mixing with them we find the highest percent recorded by Balanites aegyptiaca and does not exceed 4.8% of total vegetation cover.

3. Scarcity of some trees where were extending in the past and recording zero in cover such as A. seyal vor seyel, A. tortillis vor tortillis; Maerua crassifolia and others.

4. scarcity of long living grasses and herbs extending in the past such as I. oblongifolia, Cymbopogon proximus; Cymbogogen nervatus and Desmestachya cynosuroidea which are nutritive to human.

5. Deterioration of quantitative and qualitative structure of valuable grazing grasses and herbs Schoenefeldia gracilis; Blepharis edulis; Aristida spp; Ipomea cardoiospelala; Urocboa trichopus; Arianthema pentanda; Tephrosia spp; Penniseetum pdystachyum; Euphorbia aegyptiaca and Limeum viscosum.

6. There are obvious changes in physiologica appearance concerned with size and shape of a tree, leaves, fruits, (liha), and slow growth and so on.

7. Sppearance of new intruding and invading plants capable for competition and extension with low nutritive value for animals such as Cassina senna; by 36% cover; Guiera senegalensis by 19.6& and B. marrubifolia which represent the highest percent in percent of plant cover.

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11

Development of wastes disposal management In Khartoum area within challenges of urban growth During the period 1998-2013

11

Development of wastes disposal management In Khartoum area within challenges of urban growth During the period 1998-2013(*)

Sudan has witnessed rapid urban growth in recent decades as a result of various reasons, the most important of which are the drought conditions that affected large areas in western Sudan and the war conditions in southern Sudan and Darfur, which drove many citizens to migration. There is also migration from other regions of Sudan linked to the search for better living conditions or for jobs and civil services such as education and health. As a result, the residential area in the cities expanded, and what is known as the unplanned housing pattern appeared; the villages around the geographical perimeter of the cities were transformed into urban areas; and many residential plans were distributed to accommodate the city's original residents and immigrants from other regions in Sudan. Urban residents need solid and liquid waste disposal services with high efficiency that enable them to maintain a healthy urban environment.

(*) Co-authored with Mai Abdel-Azim, University of AL-Zaia'a Al-Azhari, Dept. of Geography..

The Khartoum region occupies an important position in Sudan due to its political and economic importance in Sudan. It witnessed by an accelerating and significant urban growth where the availability and efficiency of waste disposal management has become necessary and a major challenge for the competent authorities. Regardless of the efforts exerted to manage wastes disposal systems in the Khartoum region during the period 1998-2013, but the rapid urban growth created a major challenge that resulted in many environmental and health problems. Given that the waste disposal service is considered an essential component of the global urban system, we find that Sudan is constantly following the example of contemporary urban societies in order to be able to keep pace with the dynamism of rapid urban growth.

Khartoum State has developed over the last three decades, as its population multiplied 140 times during the period from 1905-2000, and the populated area multiplied 250 times during the same period (Al-Bushra and Othman, 2005). The Khartoum region, or Khartoum locality, continues to be an integral part of this process. The uses of its land for various purposes have developed, its neighborhoods have expanded to the outskirts, its population has multiplied several times, and its levels of urbanization and needs have varied. With this development and expansion, the amount of waste has increased especially household waste, the amount of which rose in Sudan in general from 2,862,680 tons in 1975 to 5,282,550 tons in 1995. In March 2002, household waste constituted 55% of the total amount of waste in Khartoum State, followed by commercial waste at 25%, then factory waste by 13%, and medical waste by 7%.

The contents of household waste in the Khartoum region, , include organic materials by 30%, wood by 1%, paper by 4%, glass by 1.27%, ash and dirt by 50.35%, and some other types of wastes (Greater Khartoum Region Cleaning Project, 2003). The problem lies in how to manage waste with its steady increase in volume, and the methods used in collecting, transporting and disposing of it. There is a disparity between the neighborhoods of the Khartoum capital - which includes the largest number of neighborhoods in the Greater Khartoum - in terms of population and income levels, its extension towards the outskirts, and the emergence of slums. This has led to an exacerbation of the problem accompanied by traditional methods used that do not correspond with the increasing volume of waste produced.

Solid waste management in terms of collection, transportation and treatment has become a vital matter for maintaining public and environmental health. Many countries have paid great attention to this issue, especially developed countries where the amount of solid waste generated by each individual is high. Therefore, managing solid waste in any place in an organized and correct manner requires knowledge of the quantity and quality of waste in that place, especially since it varies from one geographical place to another within a single city depending on many factors.

Data sources:

There are primary sources which included field visits and personal interviews with responsible authority for waste management (Presidency - Khartoum Locality). There are secondary sources included official reports in Khartoum locality, and relevant published research.

Theoretical framework:

The increase in the volume of waste and the multiplicity of its sources has environmental dimensions that are dangerous to human health. The problem of waste management and disposal has become more severe as a result of increasing rates of population and urban growth, social change, the development of industrial activity, and the rise in the standard of living. According to the World Health Organization, waste is defined as “some things that are no longer wanted by their owner, in a place and at a time, and are of no value or importance (Abdel-Gawad, 1997). As for the World Bank, they are “things that have become worthless in use” If it can be recycled so that it can be used or some of its components can be extracted, then it is not considered waste”

(Abdel-Gawad, 1997). There is a final definition of waste as non-liquid or gaseous materials that have been excluded by their owners because they have become useless or valuable (Babiker, 2008).

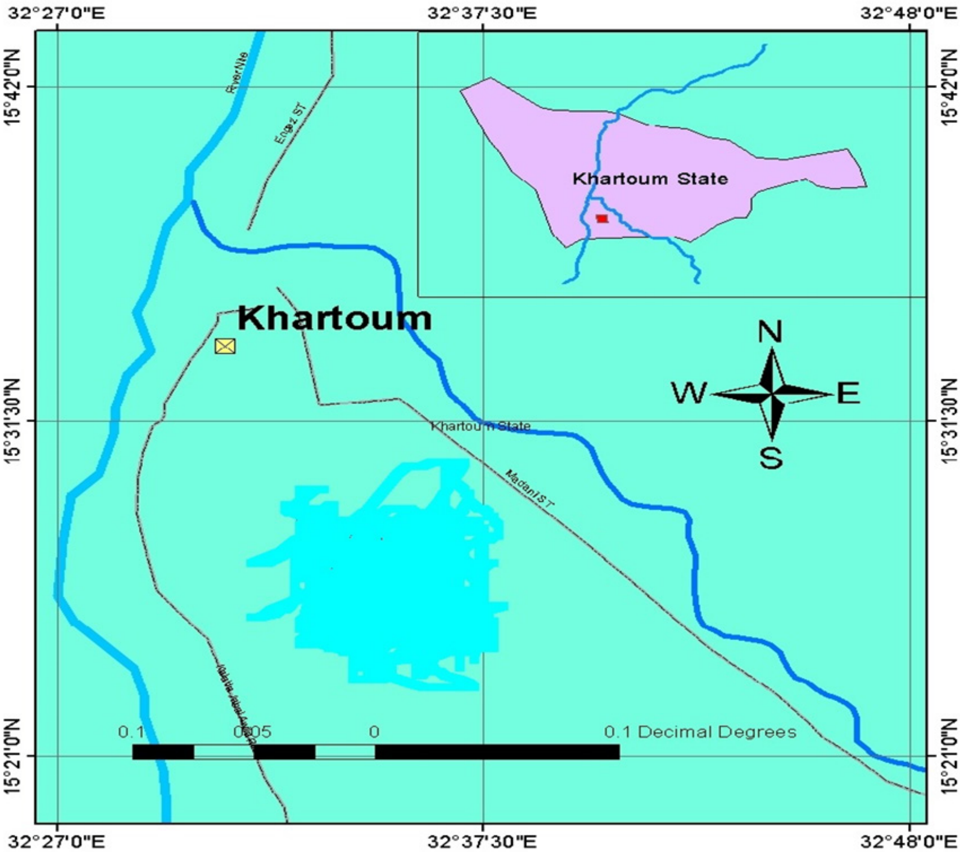
Waste is classified according to its components into four types: dry rubbish, wet garbage, ash garbage, and special garbage, which includes dead animal waste and vehicle debris. It is also classified by source into industrial solid waste, domestic solid waste, agricultural solid waste, waste resulting from wastewater treatment or sludge, mining waste, commercial waste, demolition and construction waste, and municipal services waste (Babiker, 2008). Solid waste is one of the most important and dangerous types of waste. It comes in many forms and is classified in several ways. Each type includes multiple types that vary in size, degree of humidity, content of flammable elements, and the calorific value resulting from their ignition.

Social factors, including social awareness and multiple patterns of consumption, and economic factors, including the level of income, the degree of industrial progress, and the level of urbanization, including the housing pattern, the pattern of land use, and urban growth, affect the quantity and quality of waste. In addition to that is the way factories use packaging materials, preservatives, and bags, especially if they are made of non-toxic materials, biodegradable or recyclable. Also affecting are the geographical location, climatic factors, the size of the region and community, the variation in types of waste during the year, the degree of recycling and use, and laws and legislation.

Study area:

Khartoum State consists of three regions: Khartoum, Omdurman, and Khartoum Bahri. Each region is divided into a number of localities, where the Khartoum region includes the two localities of Khartoum and Jabal Awliya. Khartoum Locality (Map 1) is considered one of the largest localities in Khartoum State, with a population of approximately 1,206,000 people (Khartoum Locality, 2005). It includes within its geographical borders and administrative sites many residential neighborhoods of the first, second, and third classes (Map 2). It is bordered to the south by Jabal Awlia locality, to the southeast by Al-Kamilin locality, to the west by Omdurman locality, to the north by Khartoum Bahri locality, and to the east by East Nile locality.

Map (1): The geographical location of the Khartoum (local) region,



Khartoum Locality consists of six administrative units; each unit includes a number of residential neighborhoods (Khartoum Locality, 2005). They are:

(1) Khartoum Unit: It includes the neighborhoods of Tuti - Al-Muqrin - Khartoum Central - Khartoum East - Khartoum West - Al-Matar District

- Buri Al-Mahs and Garden City - Buri Al-Daraissa - Al-Kuriya - Buri Al-Lamap - Nasser Extension - Al-Safa District - Buri Abu Hashish.

(2) Central Khartoum Unit: It includes the neighborhoods of Al-Mazad - Al-Shabiya - Deem Al-Ta'isha - Deem Central and East - Deem Central and West - Al-Qanabarti and Al-Atta - Al-Sajana East - Al-Sajana West - Al-Masaken and Unified Police - Al-Sabaq Neighborhood - Al-Mayqouma Neighborhood - Al-Jawam'a - Khartoum South - Khartoum (3) - Khartoum (2) - Al-Amarat - Al-Zohour District.

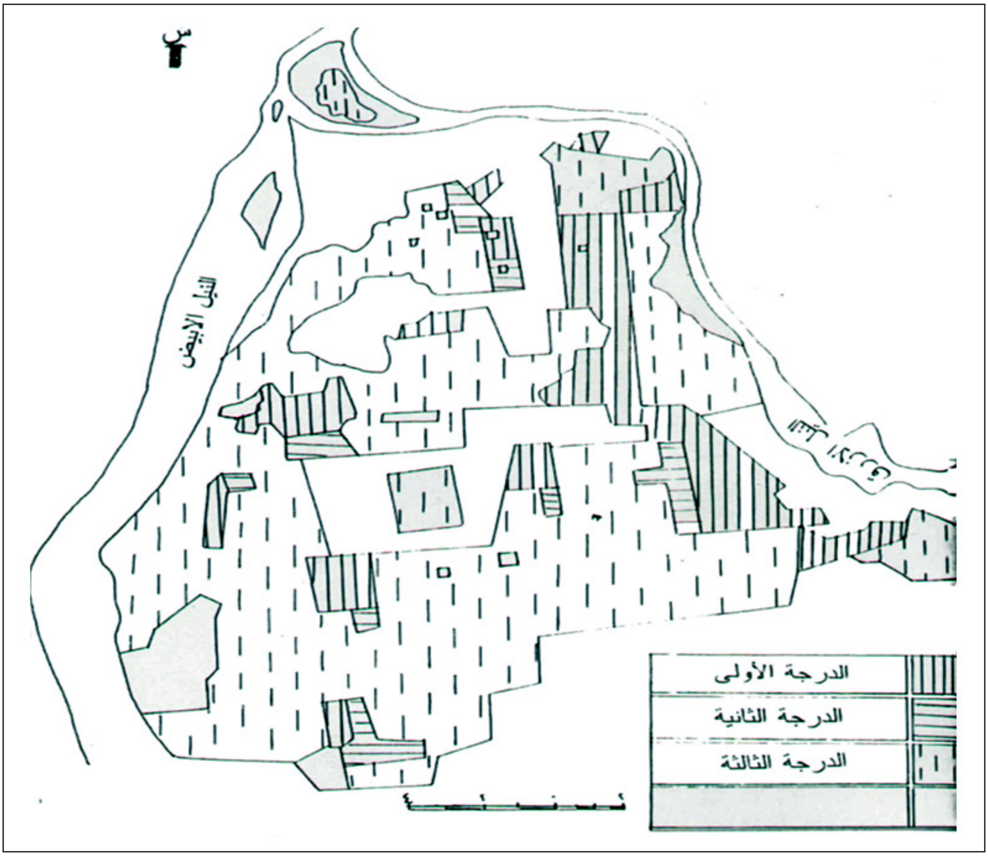
(3) Khartoum West Unit: It includes the neighborhoods of New Hilla North, New Hilla South, Al Quoz North, Al Quoz South, Al Rumaila, Al Hurriya Residential Area, and the Martyr Wada' Allah Ibrahim area.

(4) The Al-Shajara unit: It includes the neighborhoods of Al-Lamap - Bahr Abyad - Al-Lamap, Al-Fatimiya neighborhood, and square (5) - Al-Shajara Al-Hammadab - Al-Azozab - Wad Ajeeb - Al-Dabasin - Yathrib.

(5) Al-Shuhadaa and Suba Unit: It includes Al-Sahaqa East - Al-Sahafa West - Al-Sahafa Central - Al-Sahafa South - Al-Ashra - Al-Ittidha - Al-Nuzha - Jabrah North - Jabrah South - Soba Al-Hilla - Soba Al-Mahatta - Soba Al-Ibhath - Local Market - Central Market.

(6) Khartoum East Unit: It includes the neighborhoods of Arquit - Al-Maamoura - Riyadh Al-Manshiya - Taif North - Taif South - Al-Firdous - Al-Jarif.

Map (2) residential levels in the Khartoum (local) area



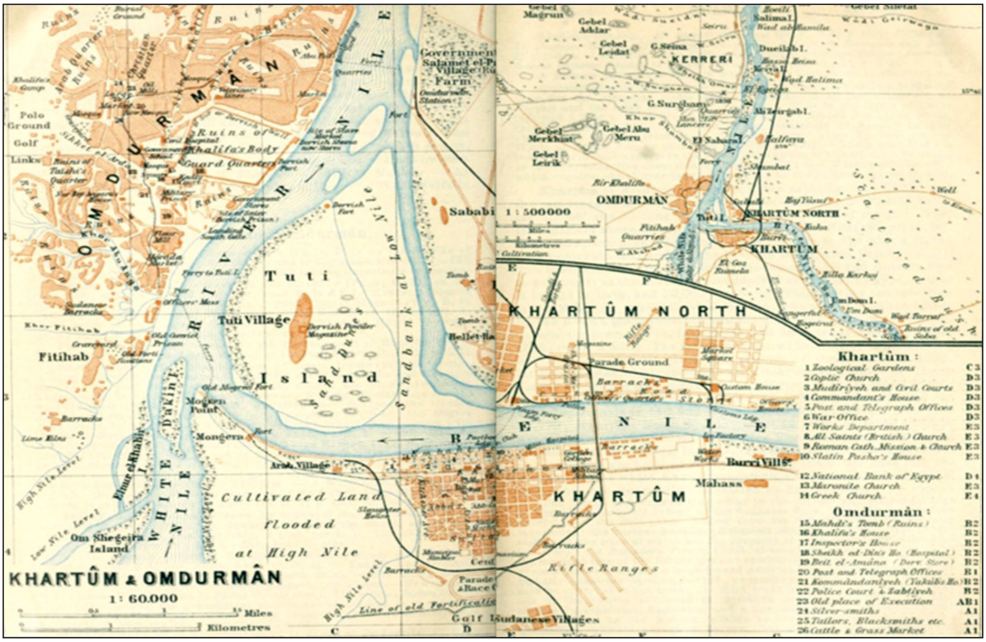
Source: Survey Authority 2000 AD

Urban growth of the Khartoum region:

Urban growth here includes all types of land use in the Khartoum urban complex. The city of Khartoum emerged as the political and administrative capital of Sudan during the period of Turkish-Egyptian rule of the country (1821-1885). It expanded at the end of its reign to the area between the Zoo (currently Al-Fatih Tower) in the west, and up to the Ministry of Health buildings in the east. Administrative and commercial institutions and upscale neighborhoods such as the Al-Hakimdar neighborhood and the Mosque neighborhood were concentrated in this area. During the Mahdism period, Omdurman became the national capital, and then Khartoum returned to become the capital during the Anglo-Egyptian rule (1956-1998).

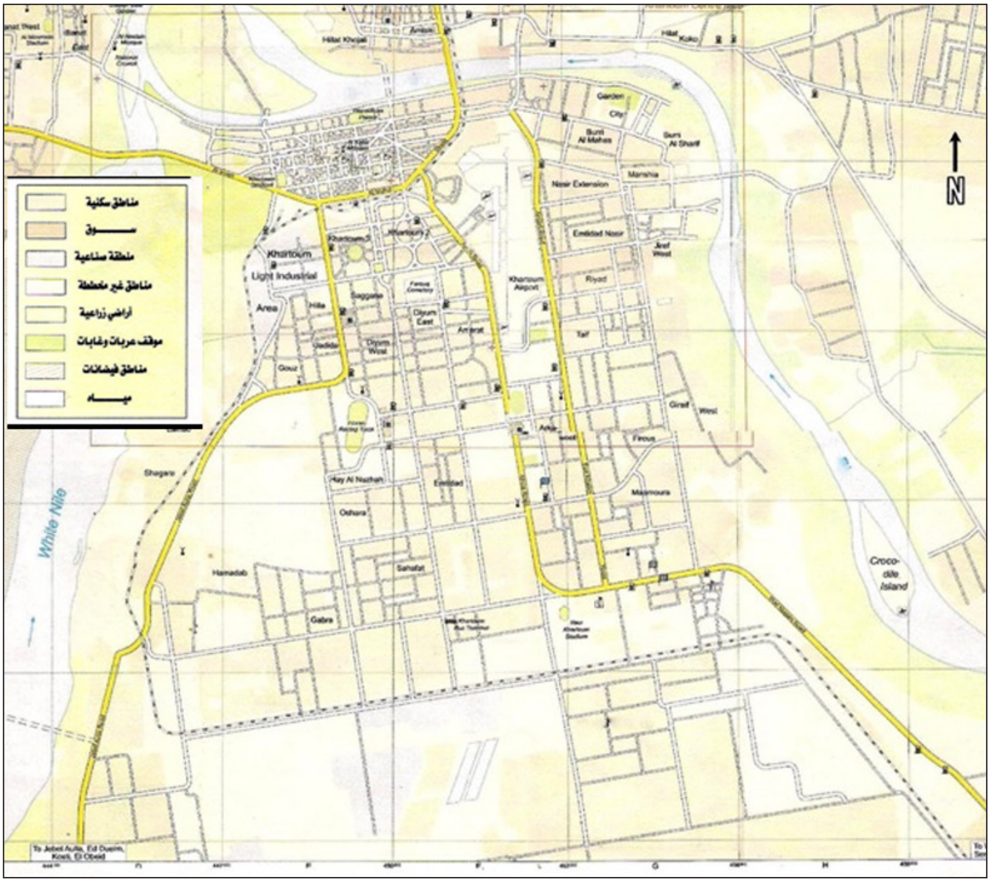
During the Anglo-Egyptian rule horizontal expansion of the city of Khartoum went through several phases. In the first phase, the city's extension did not exceed the old fortification line that surrounded the city (Map 3). As a result of civilizational progress, commercial growth, and economic expansion at the country level, the city attracted large numbers of residents in the second phase where new residential and service extensions were added. The Al-Dayoum area appeared as a residential area south of the railway station, as well as neighborhoods of Khartoum "One", and Khartoum "Two", and "Three" (Map 4). Khartoum town began to expand easternwards and southernwards where the eastern side designated for the upper residential classes and the southern side designated for the people's sectors (Abu Salim 1970).

Map (3): Layout of Khartoum in 1914



Source:https://ar.wikipedia.org/wiki/File:1914_map_Khartum_and_Omdurman

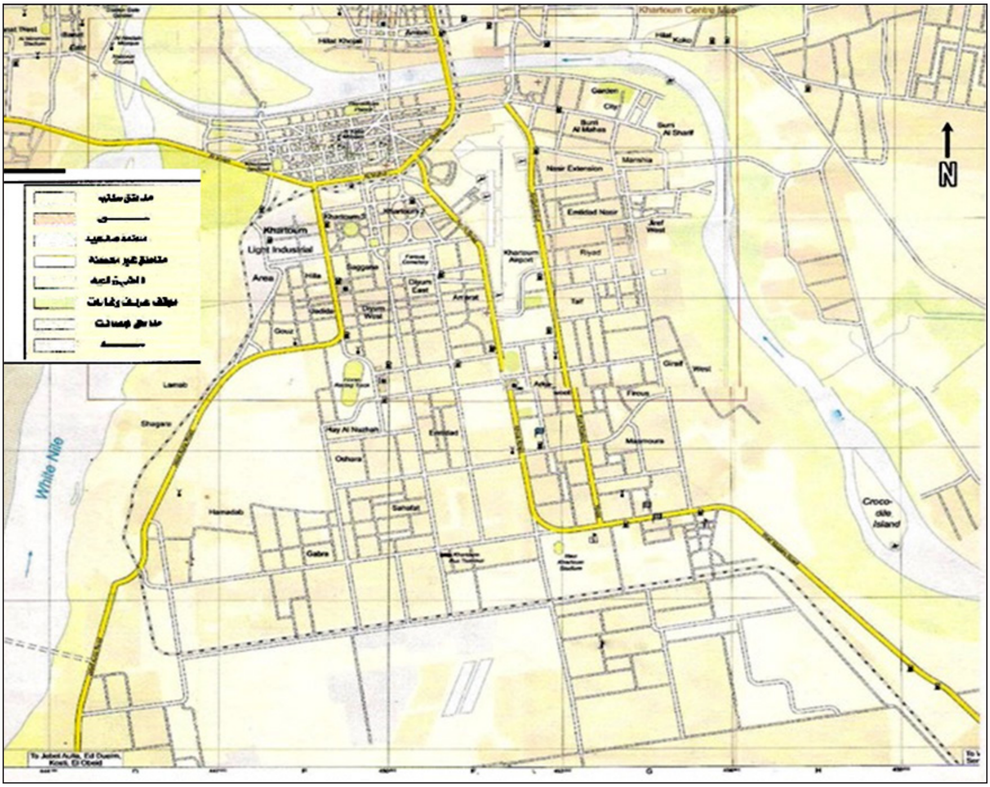
Map (4): Land uses in the Khartoum region - Part One



Source: German Embassy Khartoum in cooperation with Al-Nilein University

With the emergence of industry during World War II, the area southwest of the railway station was planned for light industry. Until the end of this period, suburbs appeared that were established outside the municipal plan, such as the areas of Al-Shajara, Al-Lamab, Al-Azozab, and some of the outskirts of Al-Jarif, in addition to the expansion of the previously existing suburbs, such as the prairies on the left side of the Blue Nile (Map 5).

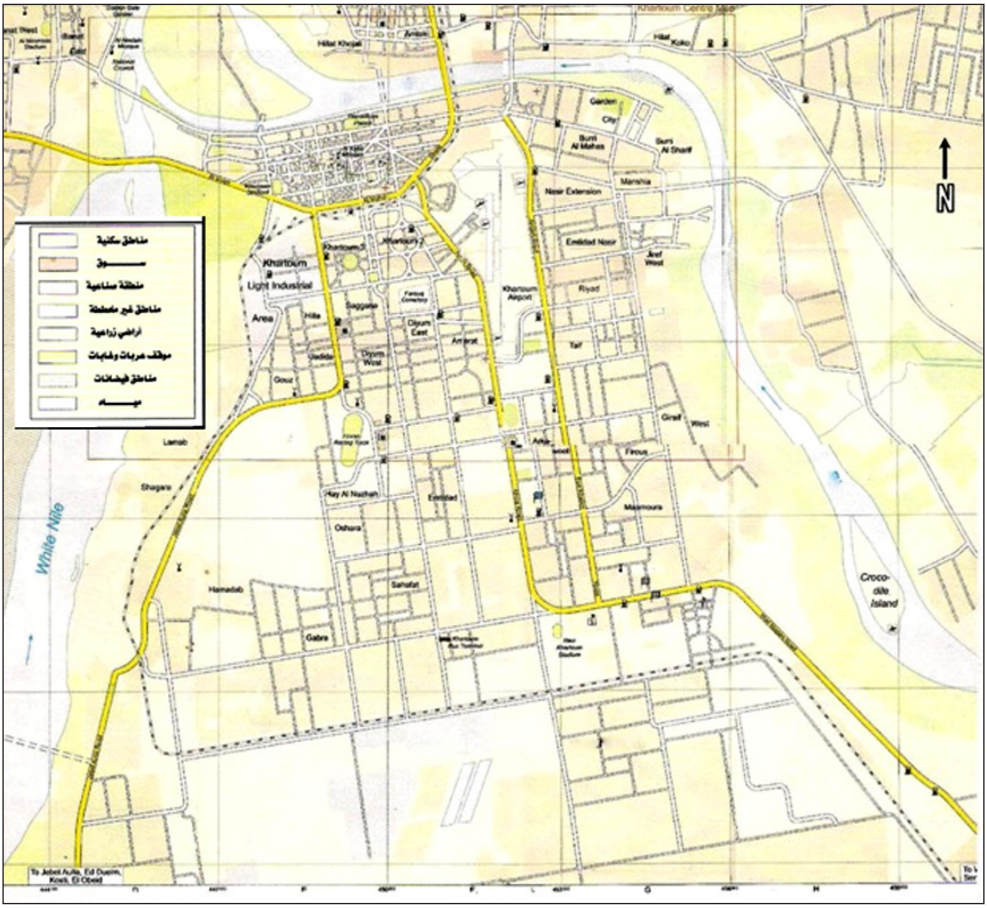
Map (5): Land uses in the Khartoum region - Part Two



Source: German Embassy Khartoum in cooperation with Al-Nilein University

In the period after independence (1956 - now), this phase witnessed the largest expansion of the city in the same previous directions on the White and Blue Nile axes. Since the end of the seventies, the city began to be surrounded by informal housing and grew significantly during the eighties, as informal neighborhoods spread from the south of the Green Belt (Mayo - Ad Hussein - Al-Salama - Soba West). The nineties were characterized by the treatment of informal housing and the re-planning of large areas of the city, within the framework of the implementation of the Structural Plan for Khartoum (1992-2002 AD), which led to further expansion. These treatments also included the distribution of land on the outskirts of the city and the removal of informal housing, in addition to the distribution of residential land. New areas developed in vacant areas within the city, such as the green belt area (Map 6). Table (1) summarizes land uses in Khartoum locality for the years 1972 and 2000 and the changes that occurred over a period of twenty-eight years.

Map (6): Land uses in the Khartoum region - Part Three



(Source: German Embassy Khartoum, in cooperation with Al-Nilein University

Table (1): Development of land uses by area in Khartoum locality, 1972 and 2000

	2000		1972
Area	%	Area	%
4,907	2.2	4,928	2
0,065	00	0,053	0
1,301	1	0,956	0
0,223	0.1	-	-
3,301	1.3	1,22	0.5
1,107	0.5	3,338	2
0,73	00	0,262	0
111,093	49.2	24,486	19
0,963	0.4	0,738	0
31,513	14	32,514	14
8,28	4	3,623	1.5
0,97	00	0,540	0
0,517	00	0,794	0
22,917	10	36,856	16
10,927	5	1,490	1
22,703	10	96,133	42
2,449	1.1	0,472	2
1,6	1.0	1,303	1
225,567	100	227,700	100

Lnd use for housing purposes:

Given that residential use occupies a large area of the Khartoum region compared to other land uses, as a result of the increase in demand for residential areas due to the natural increase in population and migrations from different regions of Sudan (Map 7). This is also considered one of the biggest obstacles to waste management, so we will give it some detail here. The use of land for housing takes several types:

Planned housing type:

It is distributed based on the plans directed to the state according to a specific plan in specific time periods. The planned housing is divided into three grades: first, second and third, and differ in terms of area, shape and type of materials used in construction. First-class buildings are vertical buildings constructed of iron, cement, concrete, and red brick, with an area of up to 500 square metres. As for second-class buildings, they may be constructed from the same building materials used in first-class buildings, with some of them being limited to using only red brick, with an area of up to 400 square metres. As for third-class buildings, they are constructed of red brick or clay and have an area of up to 300 square meters (Cutter 2006).

These standards are not fixed, but can be considered as general features. In the recent period, the areas of these levels have been shrinking as a result of the increase in demand for housing. Thus, one level has become different in its characteristics between its internal and external parts. For example, the area of the third level in the new plans has become no more than 220 m2, while it was previously 300 m2, and even exceeds that in some neighborhoods. It reaches 400 square meters, such as Al-Sahafat neighborhoods, for example. In addition to the housing plan, there is also what is known as residential complexes allocated to specific areas, such as Qashlaq police station in Khartoum South and railway houses.

Map (7): Urban growth in Greater Khartoum (1900-2000 AD)

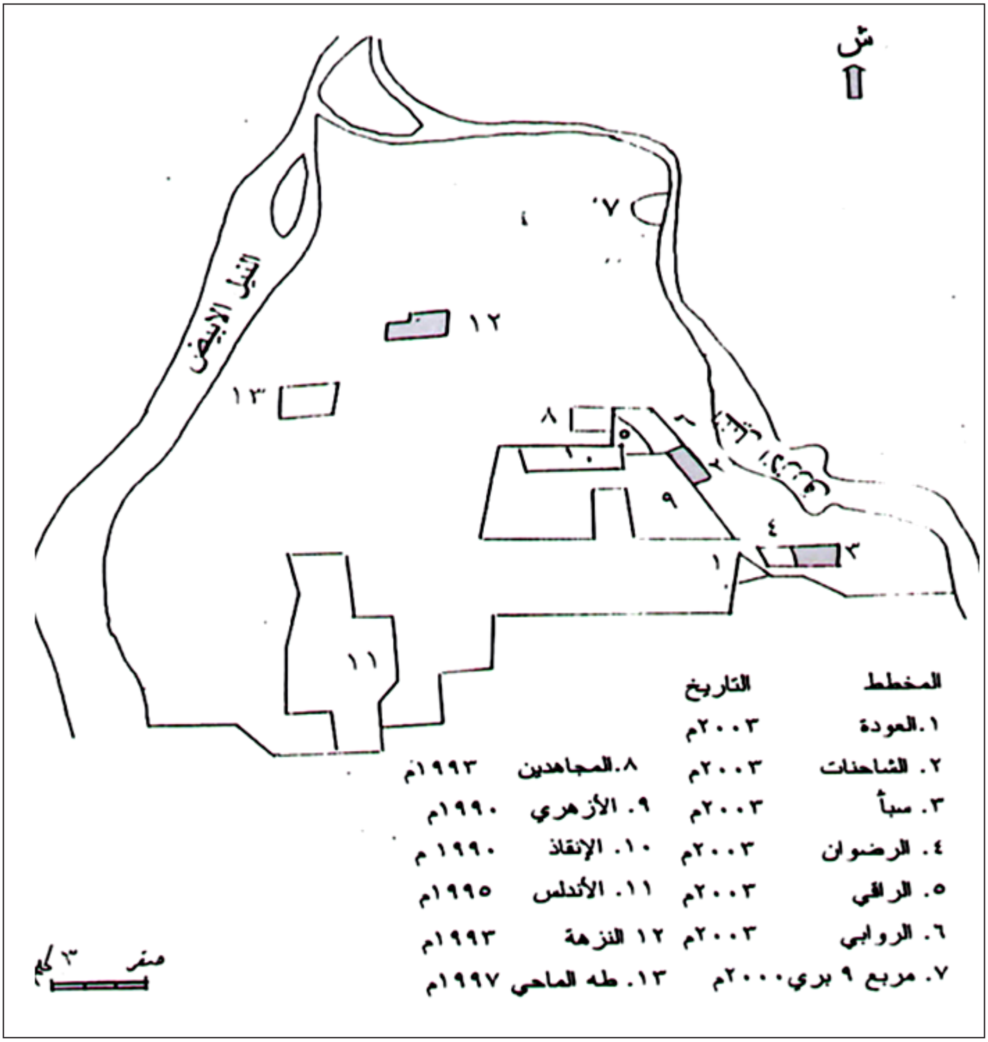
Source: Al-Bushra, Taha, 2005.1

Recently, what is known as public housing is considered a form of planned housing, where buildings are constructed with certain specifications and sold to citizens in comfortable installments. Examples include public housing west of Al-Azhari city, east of Kalaklat, and others. This pattern includes areas where re-planning has taken place, such as Al-Jarif, Al-Lamab/Al-Shajara, which are old villages that have been re-planned.

The first class is considered the best class in terms of specifications. Many neighborhoods of these classes have appeared within what is called investment housing, in which vacant spaces within the city were exploited and sold to expatriates and people with high incomes.

Examples of them are Nuzha neighborhood and the Mujahideen neighborhood. In addition, modern first-class residential neighborhoods those are equipped with all services, is distributed such as the Saba plan, Al-Radwan, and others (Map 8).

Map (8) of some modern residential plans in the city of Khartoum



Soure: Ministry of Urban Planning - Planning Department, 2005.

Organization of villages:

These villages were formed either as a result of rural migration to the city or old villages that had existed for a long time, then the city crawled into them and became part of the city’s borders in its rural form. They have prompted the Planning Department to introduce what is called village organization. These villages are characterized by their narrow streets and the disproportionate size of their buildings. In general, it is located on the outskirts of Khartoum city, examples of which include Al-Salamah - Mayo - Fatih Al-Aqliyin - Ad Hussein - Al-Kalkalat.

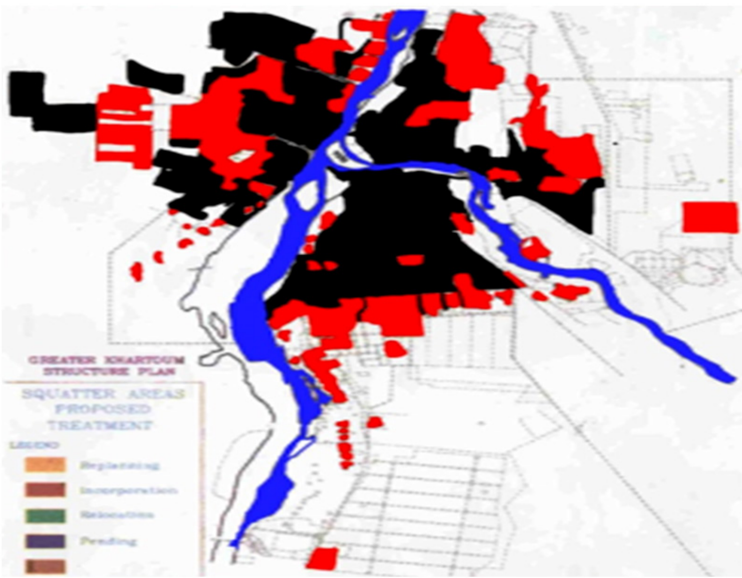
Informal (slums) housing:

It is located on the outskirts of the city and is characterized by houses being crowded into narrow spaces, the streets being alleys, and poor services. It is characterized by the fact that it is not compatible with the urban fabric of the communities that grow around it, is inconsistent with the natural trends of growth and expansion, and is in violation of the laws regulating urbanization. The growth of informal housing in the Khartoum region has gone through several stages. In 1983 AD, it occupied 17% of the total area of the urban area of Khartoum State, then it rose to 40% in 1985 AD, then to 60% in 1990 AD, then it decreased in 2000 AD to 20% as a result of various efforts by the official authorities in the state (maps 9 to 11).

Map (9): Slum housing areas in 1985 AD

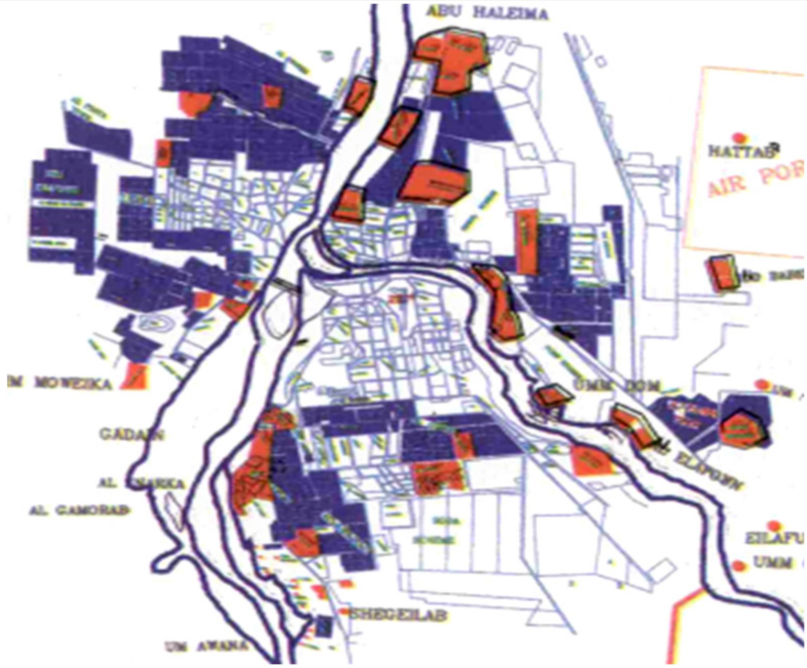
Khartoum Slums in 1985 (40%)

Map (10): Slum housing areas in 1990



Khartoum Slums in 1990 (60%)

Map 11: Slum housing areas in 2000 AD



Khartoum Slums in 2000 (20%)

Informal housing has many types, some of which are based on building materials and are represented by cardboard, tin and wood huts and small mud rooms. The majority of their residents are newly displaced rural people who are a mixture of ethnic affiliations and different tribes. There are temporary tents that represent crowded (traditional) informal settlements. There are also buildings incomplete constructions in the planned areas where some of these immigrants reside. There is also luxury slum housing, which is houses with a higher construction level than traditional slum housing and was built in areas that were not originally designated for housing.

Land ownership in informal housing includes lands registered in the name of the Government of Sudan, and vacant lands that were not planned for any purpose. There are also lands that have been planned and included in the housing plan, such as Dar Al Salam squares in the

Jabal Awliya area. There are slums in industrial zone lands, such as the Omdurman Industrial Zone and the Bahri Industrial Zone. There are also slums in some agricultural lands in Al-Jarif West. As for informal housing, according to its exposure to planning, it includes informal areas that have been replanned and integrated into the urban fabric of the city. There are areas that have not been replanned, such as some parts of the Mayo area, the cities of Dar es Salaam that were not originally present in the city plans but were created by the conditions of displacement, and the villages that have been integrated into the urban environment of the city despite its rural character.

Solid waste management in the Greater Khartoum before 2001 AD

Responsibility for solid waste management in the Greater Khartoum fluctuated between the localities and the state Ministry of Health for a long time. Cleaning operations were characterized by traditionalism, and there was no system that kept pace with existing systems in the world for cleaning cities, which led to a clear decline in environmental health. The lack of machinery at that time greatly affected cleaning operations, as localities and the Ministry of Health failed to develop capabilities and develop plans to implement them. An example of this is that the available machines were from the Japanese grant, as they had many malfunctions and were not provided with the required maintenance, in addition to the inability of localities to provide sufficient labor for cleaning operations due to their inability to pay financial obligations, lack of qualification of technical personnel, and lack of coordination.

All of these reasons constituted an obstacle to the proper management of solid waste, especially since the responsibility fell on one official in the locality who carried out other tasks related to aspects of health, engineering, accounting, and health education. This contradicts the theory of modern management, which is the necessity of specialization in business. As a result, in 1998, it was found that 55% of waste was thrown out in the open, 35% of it was burned, and what was collected was only about 10% (El Agraa, 2002). The Greater Khartoum reached deteriorating conditions and random dumps spread, and it became important for the responsible authorities to intervene to correct the situation.

Emergency program for environmental sanitation, April 2001:

During the 1980s and 1990s, Khartoum State experienced a significant deterioration in environmental health due to inadequate waste disposal services, which led to its accumulation in residential neighborhoods, markets, and industrial areas. The prevailing treatment methods were burning waste on site, which caused a lot of inconvenience to residents of the neighborhoods. To remedy the situation, the state established an emergency program for environmental sanitation. Accordingly, technical cadres from health, engineering, and administrative cadres were assigned to manage waste operations within the framework of a program that specializes in cleanliness as a primary focus and removing the existing accumulation as an experiment for management in the waste disposal process through a specialized body that does not have additional burdens as was the case with the municipalities previously (Ahmed, 2007).

One of the most important objectives of the program was to work to limit and remove the accumulations of disposal sites in residential, commercial and industrial neighborhoods, and to unify the final disposal area by identifying a temporary site and equipping it with all the primary machinery for practical and sanitary treatments. Also, to work on preparing cells with a depth of 6 meters and dimensions according to the area available in the sites temporarily, and to bury the waste on a daily basis in a temporary layers in a way that improves the environment. Indeed, some sites that were used randomly were exploited and rehabilitated in the form of cells filled with waste in the form of layers (two meters for each layer), separated by a sand layer 25-30 cm thick, and the number of layers ranges from 3 to 4 layers.

As a result of the emergency program's focus on removing existing accumulations and laying the foundations for a system that prevents accumulation in the future, it succeeded in achieving its goals, and the quantities transported during the first period of the program amounted to (700-800 cubic metric tons/day), as more than 163,770 cubic meters of accumulated waste were transported in the program was also able to organize a collection, storage and treatment service for between 600-900 cubic meters of waste per day and treat it completely in one site prepared hygienically and engineeringly in order to avoid any new accumulations.

The increase in the number of machines and direct labor, in addition to the modernization of methods, was reflected in the increase in the amount of waste transported from year to year. The great success achieved by the emergency program played a major role in encouraging the state to spread the idea in both Omdurman and Bahri towns and to establish a project specializing in solid waste management in Khartoum State. The project was actually established in accordance with Resolution (23) of 2003 AD.

Greater Khartoum area cleaning project for the year 2003:

The Greater Khartoum Region Cleanup Project for 2003 aimed to achieve a number of goals, including cleaning the state according to modern methods and following the best means of waste storage and treatment techniques, providing the minimum amount of human and mechanical power to conduct the work, establishing final dumpsites and intermediate stations according to engineering and sanitary specifications, and developing scientific plans and programmes. This is to ensure business continuity, apply scientific standards to serve the collection, storage, transportation and treatment of waste, qualify and train cadres, and raise citizens' environmental awareness. To achieve these goals geographically, the Khartoum town was divided into six sectors to facilitate cleaning operations. They included the Khartoum sector, the central Khartoum sector, the western Khartoum sector, the Shajara sector, the eastern Khartoum sector, and the Shuhada and Soba sector. The rates and areas of service were determined, as the rates of provision vary depending on the locations and their type, and there are a number of locations that are covered according to specific programming, such as private institutions (Table 2).

Table (2): Sites, Number, percentage (%), and rate of service provision in the Khartoum region

Sites	Number	%	Rate of service
Houses	250100	40	Daily
Markets	70	64	Daily, 2-3 rotations
Streets	297	88	Daily, 2-3 rotations
Wtaer Drain Channels	224	94	Daily, 1-2 rotations
Squares and vacancies	479	82	Daily, 2-3 rotations
Containers and barrels	755	94	Daily, based on number available in program
Squatter area for execreta	961	93	Daily, based on number available in program
Siltes of insect breeding	920	55	Daily, based on number available in program
Private corporations	874	96	Daily, based on number available in program
Monthly treechopping	171	93	Daily based on number available in program
Manual cleaning	27	100	Trice a week

Source: Greater Khartoum Cleaning Project, 2003

New methods in the project:

The project used a number of temporary storage methods for the residential, commercial and street sectors according to a well-studied timetable to ensure complete protection from the dangers of waste. This included plastic bags and 2 cubic yard containers that are used on main streets, multi-storey buildings and in residential sectors as an additional storage factor with plastic bags. Smaller containers with capacities of 180 liters and 100 liters can also be used on the streets. It also provided 4.5 cubic yard containers for commercial complexes and some neighborhoods. They are characterized by their large capacity and ease of unloading in the pressure ferry, which saves a lot of time and labor and is one of the most common types in use. As for the 14 m3 container, it was mainly provided to factories, workshop complexes, and commercial markets, especially vegetable, fruit, meat, and fish markets. It is also used in public squares and parks, which represents a practical framework for the large size of the container and the ease of unloading it into cranes.

As for the transport methods, the backhoes included between 4.3 meters and 30 cubic yards, and they were loaded either mechanically using containers or manually by direct workers. As for cranes, there are hook cranes that are used to lift containers of 20 cubic meters and 14 cubic meters, and boom cranes that are used to lift containers of 5 cubic meters. The project focused on the first type of container. As for dumpers, the rear compactors do not serve all waste purposes, which necessitate the presence of other means of transportation, especially for demolition waste and large-sized waste and pieces. Therefore, dumpers are used for this purpose in addition to their work in final landfills.

There is mechanical sweeping, which has been done manually for many years and requires a large number of labor and auxiliary tools. Despite these efforts, the cleaning operations were not sufficient to highlight the aesthetic aspect, especially in the sovereign streets, so the idea came to provide a high-tech mechanical sweeper and test it in some selected streets in preparation for applying the idea to all streets if it proved its practical and economic feasibility. The above-mentioned machinary work side by side with the old machinaries that the project inherited, including rear compactors, dumpers, cranes, and tractors, and the deficit in the current number of transport mechanisms is covered by renting from the private sector. As a result of these efforts, the project succeeded in transporting 268,747 cubic meters of waste in 2002, which increased to 1,131,500 cubic meters in 2008. A number of landfills were also constructed, in which large quantities of solid waste were buried (Table 3).

Table (3) Landfill locations and buried quantities

Site name	Period	Quantity absorbed/cm3
Al-Lamab next to the Egyptian irrigation system	4/6/2001 until 5/18/2002	162,770
Nile Club Landfill	5/15/2002 until October 2003	545860
-Azhari landfill next to the Meta Iron Factory	January 2004 until April 2004	31951
Al-Salamah landfill, next to the International University of Africa	January 2004 until April 2004	70029
Al-Lamab landfill next to the Egyptian inspection	7/24/2004 until 7/31/2007	11050
Al-Dukhinat landfill near the city of Hope	7/25/2004 until 4/20/2007	662657.5
Suba landfill	8/25/2004 to 10/21/2004	41085
Whole Total		1,525,403

Source: Khartoum State Cleanliness Project Administration, 2008

Waste disposal management challenges for the 2003 programme:

The waste disposal management project faced many challenges that can be explained within the general results and specific results of Abdel Azim’s (2008) study. As for the general results, previous experiments failed and their departments faced technical problems because they were not specialized in waste management. Therefore, the emergency solid waste management program is considered an unprecedented experience since it was conducted under the supervision of a specialized waste management department. The project's work was limited to collecting, compressing, treating and final disposal of solid waste, and did not carry out any sorting or recycling operations, which created another challenge.

Despite the success of the project in treating waste temporarily at the intermediate station in Al Quoz (south of Khartoum) by sorting and compressing the materials and then transporting them to the final landfill stations in Jabal Abu Walidat in Omdurman, and finally disposing of them by burial according to specifications closer to scientific specifications, a challenge has emerged, which is that the bottom of the cells is not lined with materials, insulating, which may pose an environmental hazard. Among other challenges, the program lacks a scientific methodology in the complete management in terms of classification, sorting, reuse, recycling, and safe disposal of solid waste. The project also faced a major challenge, which is the lack of equal provision of services to residential neighborhoods.

The central Khartoum area received the largest share of the services provided in the project compared to the outskirts of the city, which has the highest rate of waste generation due to the steady residential extensions and the presence of informal housing areas. The project's reliance on hired labor created a major challenge combined with the weak level of environmental awareness and low civilized behavior among citizens. The project also faced special difficulties in the construction of landfills due to the different surface formations in the Khartoum town area. This means the high cost of its implementation and its need for engineering specifications, according to which waste is disposed of by spreading this waste on thin layers, compressing it to the smallest possible size, and then covering it daily with an appropriate layer reduce environmental pollution.

The results of Abdel Azim's study (2008) concerned the housing and market sectors. As for the challenges that faced the project in the residential sector, the city's residential grading system affected the amount of waste produced. In this system, large areas of houses were allocated to the first and second classes, and their residents are usually of high income and their families are small in size.This in contrast to what was allocated in the residential sector where small areas of third-class houses for large families and mostly with low incomes. The difference in residential density as a result of the difference in population distribution and density depending on the area in the neighborhoods of the Khartoum region has created challenges for waste management in the region. The population of the region is distributed among more than (56) residential neighborhoods distributed between an upscale and a popular neighborhood.

As a result of the multiplicity of social and economic classes, the population density varies accordingly. In the upscale neighborhoods, the population density reaches ess than 500 person /km^2, while in the popular neighborhoods it reaches 27,000 person /km^2. In general, the average density in the city of Khartoum reaches 6,500 person/ km^2. Accordingly, the quantities of waste produced were greater in third-class residential areas compared to first- and second-class residential areas, especially since the project covered areas on a regular basis, while this service was rare or non-existent in other areas.

One of the major challenges of the project in the residential sector was its inability to keep pace with the steady increase in waste due to the rapid population increase, especially since many third-class residential areas, and even some informal housing areas, have changed their style from traditional to multi-storey housing that accommodates larger amounts of population in living conditions. The narrow streets hindered the movement of large vehicles designated for waste collection. Among the challenges were also the small number of main service centers and large containers, the spread of fences around houses or the exploitation of part of residential houses for other purposes (residential

- commercial - recreational - etc.), and the exploitation of Squares, all of which hindered the flow of service means. The rainfall season also created another challenge, as there is no service due to the absence of drains.

As for the market sector, the project faced the challenge of providing daily cleaning service in front of shops and limiting it to the collection process only. Also, the small number of containers, or their small size, allocated to shop owners did not keep pace with the amount of sorted waste, which prompted them to dispose of it in front of their shops and subsequently accumulate it inside the market streets, thus creating a challenge in the difficulty of meeting the daily reality of this sector, which is characterized by its large number of waste secretions.

In March 2011, the pilot project for waste management was launched in Khartoum State at the solid waste complex in the Al-Mugran area, where 200 baskets were distributed to protect waste from scattering and environmental pollution in cooperation with the Japanese International Cooperation Agency, and 1,000 barrels will be launched in various sectors in Khartoum locality (Akher Lahza newspaper, 2011). In 2013 AD, work was carried out on the Khartoum State cleanliness project in cooperation with the Japanese International Aid Organization (JICA) for a period of fifteen years. It is concerned with improving and managing solid waste and treating waste collection with new methods tested in Japan. It is concerned with collection and final treatment with landfills. Localities and citizens participate in the connection awareness.

A sanitary landfill was created in which waste is treated to be used for recycling, energy extraction, pollution control, and soil preservation. In addition, the project will save time, increase efficiency in operating machinery, increase the number of visits and frequency of residential neighborhoods, enable daily waste collection, and connect 15 houses in a specific place and at a specific time, in addition to environmental awareness and the development of landfills in Khartoum State (Al-Rai Al-Aam newspaper 2013).). The project faced the same challenges faced by the previous waste management project in 2003. Therefore, the reasons that led to the failure of the previous project did not disappear until this project achieved its goals. The waste crisis worsened in 2017 and reached the peak of its failure, as the city of Khartoum began to suffer from the accumulation of piles of garbage for many days, especially in the rainfall season.

Discussion:

This research demonstrated that the Khartoum town has witnessed rapid residential and population growth, which has created a challenge for solid waste management. Residential growth extended horizontally and absorbed huge quantities of immigrants, whose numbers increased since the 1970s, when more than 45% of the Sudanese rural population arrived in Khartoum State. The pace of immigration continued, as in 1984 about 120,000 people arrived there from the states of Kordofan and Darfur, and in 1987 their number was estimated about 667,000 people. When their number increased in 1990, the responsible authorities were unable to accommodate them in suitable residential areas or urban economic activities, which resulted in many problems, the most important of which was the emergence of informal housing areas (Abu Sin and Davies, 1991).

Most of these migrants came from the traditional rain-fed agriculture sector, which suffers from mismanagement, deterioration of resources, and low productivity (Hamid, el al., 2012). These migrants are classified among the 75% poor in northern Sudan, 30 % of whom suffer from extreme poverty (United Nations Development Program, 2005). Although they practice activities in the marginal urban economic sector, they have not emerged from the circle of living below the urban poverty line, which is more than 50% among the urban population in Sudan (Mahran, 2006). The low economic situation has constituted an obstacle to waste management, especially since it depends on paying the financial fees imposed on service recipients to benefit from them in providing the huge budgets required for its management.

Linked to this rapid population and urban growth in Sudan is the emergence of informal (slum) housing patterns that receive the movements of migrants to the cities ((Muindi et al. 2009). Until 1981, there was no clear presence of informal housing areas around Khartoum State, but since the year in 1983, these areas began to appear. Their percentage reached 17% of the total area of residential areas, then it increased in 1985 to 40%, and the the percentage of human settlements at that time was estimated at about 96 informal settlements surrounding Khartoum, inhabited by about 600,000 citizens, who constitute about 4% of Khartoum's population. In 1990 this percentage rose to 60%, and as a result of the treatments carried out By the responsible authorities, it decreased to 20% in the year 2000 (maps 8-12).

These informal dwellings occupied sites those are not suitable for housing, such as natural sewers and low places that are vulnerable to demolition, especially in the rainy season. It also spread in first-class residential areas under construction, public squares, and around schools and factories until the number of slum neighborhoods reached more than fifty (Banga, 1994). Therefore, it is difficult to provide waste service with the required efficiency in such areas.

Given that social change and normalization takes a long time to occur, the fact that the Khartoum town contains all the tribes of Sudan with their cultures, customs and traditions has created different social environments. This in general, can be considered an urban environment with the presence of some sites that tend toward a rural environment on the outskirts of it. Therefore, in addition to the difference in housing levels and individual income, we find that the individual behavior pattern has an influential role in creating a clean urban environment, as behavioral and cultural factors play a significant role in all its events (Babiker, 2008). As Al-Nimr (1999) pointed out, horizontal expansion in light of the weak role of urban planning negatively affects the provision of infrastructure and social services and thus the health of the urban environment. It also disrupts the uses of land and hinders the implementation of the Khartoum state's future plans, such as those related to environmental health, including waste management services..

Conclusion and recommendation:

It became clear from this study that the natural population growth of the city's residents and the rapid migration from the countryside to Khartoum resulted in a population increase that required the necessity of providing residential areas to accommodate them. The Khartoum state did not succeed, despite the efforts it made, in achieving this goal, which prompted them to search for alternatives or solutions. Slum housing areas appeared either in the form of new areas whose lands were seized and were either designated for housing plans or for various service purposes, or through direct purchase from People of ancient villages located on the geographical margin of Khartoum city, which were either natural pastures or areas for rain-fed agriculture in the past.

Therefore, the nature of the rapid and unregulated urban growth of the Greater Khartoum, and the subsequent massive population increase, is what created the greatest challenge to waste management in this region. This growth, both residential and population, does not deviate from the overall development issues in Sudan. Despite the efforts made by the state in dealing with informal housing, the problems of the Sudanese countryside, especially those associated with conditions of drought, desertification and pressing economic problems, are considered the main catalyst for the export of new immigrants to Khartoum and thus make them the first threat to causing disruption in the urban system.

Recommendation: an integrated geographical approach for waste management in Greater Khartoum

The integrated geographical approach for waste management in the Greater Khartoum depends on an integrated vision between the rural reality and the urban reality in Sudan.

First, working to solve the problems of the Sudanese countryside reduces migration to the capital and thus alleviates the burden of the waste management problem. As for the urban reality, it requires working to benefit from waste as an economic resource (Trash can become cash). Here, global and regional experiences can be useful in this aspect. To confirm this, we can provide examples. In Australia, the city of Whittlesea developed an environmental planning strategy that led to reducing the per capita waste generation rate to 0.75% kg/person/day instead of 1.5 kg/person/day (Khalil, 2005). In Brazil, Sao Paulo's environmental revolution for recycling has succeeded, as Brazilians no longer excavate mountains to search for metals, do not cut down trees to make paper, and do not pay huge sums of money to generate energy, but rather rely on recycling waste. The State of Bahrain, in cooperation with the United Nations Development Programme, worked to recycle household waste and transform it into organic fertilizer that improves soil properties using anaerobic fermentation method using treated sewage water.

The city of Riyadh benefited from the experience and established a natural fertilizer factory that receives waste from homes, shops, restaurants, tree waste, and purification plant sediments. It accommodates 33 tons per day and produces 5 tons per day, which is used in the afforestation program. In the eastern region of Saudi Arabia, waste was converted into organic fertilizers to meet the continuing demand for organic fertilizers as a result of agricultural expansion. There are also two factories in the United Arab Emirates that utilize household waste and the like and transform them into organic fertilizer. One of them covers 75% of agriculture's fertilizer needs in the city of Al Ain and its environs, where the daily production of fertilizer is 80-90 tons, and the second has a daily capacity of 100 tons (Al Hammad (1995), which led to a reduction in the cost of burying waste and its harmful effects on me.

There is the Doha Organic Fertilizer Factory, which has a capacity of 150 tons of garbage per day, including 30 tons of sewage and 120 tons of household waste. The factory has a special section for pressing metal materials into molds from which the spare parts needed by the factory are manufactured. In the State of Kuwait, there is the largest factory in the Gulf that reuses some types of glass left over from food manufacturing companies. Some institutions collect glass waste and sell it to the factory, which produces about 33 thousand tons annually.

Secondly, associations and non-governmental organizations can be used to activate methods to control the management of solid waste. An example of this is what the Environmental Association in Kelibia, Tunisia, did in selective sorting of household waste in some neighborhoods of the city. This was done by educating and motivating residents to sort waste by type using different bags (Al-Janhani, 2005).

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12

Qualitative spatial tourism specialization model for the Sablouqa region, Nile River State – Sudan;

12

Qualitative spatial tourism specialization model for the Sablouqa region, Nile River State - Sudan

Tourism is considered one of the most growing industries in the world, as it has become a productive sector that has a role in increasing national income, an opportunity to provide jobs, a cultural message, and a bridge of communication between cultures and peoples. Tourism means travel for the purpose of leisure and enjoyment, or for religious, family or commercial purposes, usually for a limited period. It is common for tourism to be associated with international travel, but it may also be associated with traveling elsewhere within the same country.

The World Tourism Organization defines tourists as "people who travel and stay in places outside their usual environment for a period of not less than one year for the purpose of recreation, commerce, or other purposes" (UNWTO 2009). Ecotourism means "travel to natural areas that have not been polluted and are not exposed to natural imbalance, in order to enjoy its landscapes, plants, wild animals and civilizations in the past and present" (www.enow.2010). Tourism development is defined as "integrated industrialization, which means establishing and constructing tourist centers that include the various services that the tourist needs during his stay in them and in a manner that suits With the financial capabilities of different categories of tourists” (Jalila 2006).

One of the highest goals of the philosophy and policy of tourism in the twenty-first century is the integration of economic, political, cultural and intellectual with the environmental benefits of tourism for the population, which results in a higher quality of life (David 2006). Tourism development is considered one of the methods to achieve integrated economic development. Therefore, tourism development is linked to social development by virtue of the fact that it works to raise the standard of living of communities, create recreational and cultural facilities for citizens and visitors, develop public places and services at tourist destinations, raise the level of awareness of tourism development among broad categories of communities, and also develop a sense of belonging. National development plans could increase opportunities for cultural and civilizational exchange between the host community and the visitor (Khan and Zawi (2010).

Tourism marketers play a pivotal role in marketing the tourist destination, especially in creating and innovating destination images and visions, which are designed to influence decision-making and behavior by the tourist. The general direction of tourism development for Qatar is provided by the tourism policy, which provides guidelines, strategies and objectives for the development of tourism (2011).). Dubai has adopted a hybrid model of tourism planning when examining tourism policy and operations there (Richard 2008). The intersection of entrepreneurship with workers in the tourism sector is also strongly associated with the growth in the number of new establishments and employment, especially in those rural counties that have attractive open services (Carol, et al., 2014).

Ecotourism constitutes the main industry of the national economy of many countries, as it contributes 11% of the total domestic production of countries such as Sweden and Kenya, and supports the infrastructure of many countries. Mountain tourism contributes to providing job opportunities for the local population and providing revenues to these areas, which contributes to stopping rural migration. At the same time, it requires controlling tourist flows in order to preserve the environment, and the impact on the local population and their culture must also be considered.

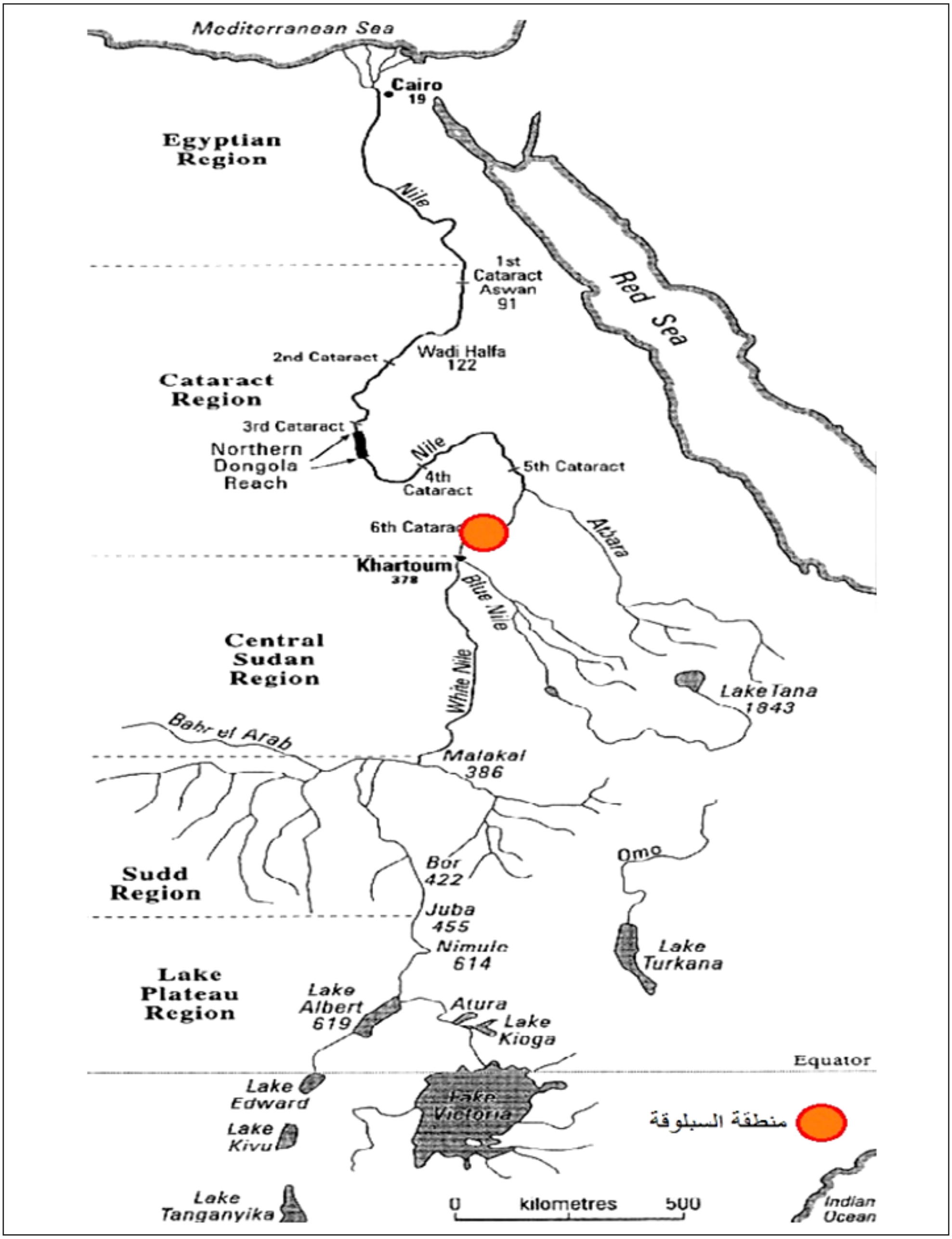
There is an expectation that the number of tourists in the world in the year 2020 will rise to 1.6 billion tourists, amounting to more than $2,000 billion (Graham 1994). Tourism contributed 10.9% of the global GDP in 1995 and provided job opportunities for about 212 million workers in tourism and the sectors in which tourism stimulates production, and who produced $673 billion in tax revenues for governments (Khariouti 2004: 18). The share of Arab countries in global tourism is still far below their potential because the tourism sector in these countries faces many restrictions, including lack of investments in infrastructure and basic services (Ali 2012).

Tourism in the Kingdom of Saudi Arabia contributes 4.6% to the gross domestic product, and is expected to contribute by 2020 by providing 1.5 million direct and indirect jobs (Supreme Commission for Tourism, Kingdom of Saudi Arabia (2003). In Jordan, tourism contributed 43% to the total revenues from exports in the year 1999 (League of Arab States and the United Nations Environment Program 2010). In Sudan, tourism demand is considered weak, which has had a negative impact on tourism revenues, such that tourism makes a weak contribution to the development process in Sudan (Khalifa 2008). The supply of tourism resources in Sudan depends on variables, the most important of which is the available leisure time. Private car ownership, the level of services provided, infrastructure development, and the allocation of facilities to different population groups (Abu Zaid 2008).

The location of Sabaloqa region and sources of data:

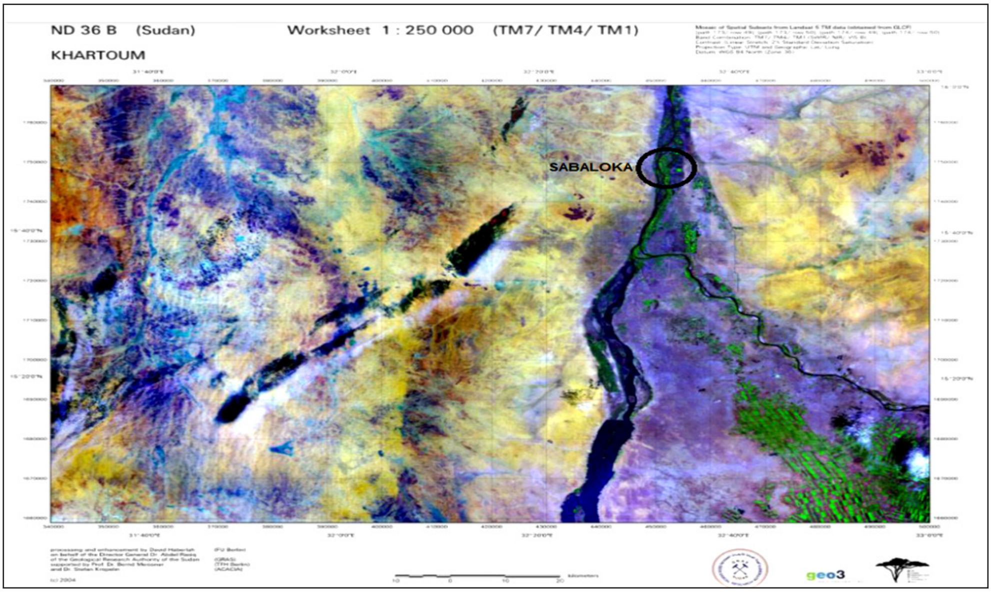
The Sabaloqa region is located north of Khartoum State and extends in the southern part of the Nile River State between latitudes 16 degrees 12 minutes and 16 degrees 24 minutes north, and longitudes 33 degrees and 33 degrees 36 minutes east (Figure 1).

Figure 1: The geographical location of the Sablouqa region



The terrain maps of Sabaloqa area issued by the Sudanese Survey Authority, and the satellite visual maps (Figure 2) issued by the Sudanese Geological Research Authority (GRAS, 2014) of the Sabaloqa region were analyzed with the aim of distinguishing the main terrain units, which helps in developing the proposed geographic model based on qualitative spatial tourism specialization.

Figure 2: A satellite image showing the coordinates, geomorphology, and geology of the Sabaloqa region



Source: Sudanese Geological Research Authority (2014)

Based on these sources, the geomorphological classification was used, which is a classification and description of the nature, origin and development of the terrain, in order to divide the Sabaloqa region into geomorphological units. The geomorphological unit is defined as the spatial unit that contains some phenomena that, when taken together, form the surface features of this unit (Oilfield Dictionary 2015). The geomorphic unit can be classified based on its origin and development (known as the principle of process), on its overall structure and shape (known as the principle of form), on the measurement of its dimensions and mophometric characteristics (known as the principle of measurement), and on the existence and status of the active process (Haskins et al., 1998).

Based on the principle of structure and shape (or shape), the Sabaloqa region was divided into four main geomorphological units on a drawing scale of 1:250,000 (see Figure 5). Each unit includes a number of smaller units. The first terrain unit included three sub-units: the area of rocky hills, the area of gravel and sand deposits, and the area of dunes and sand formations. The second terrain unit included three sub-units: the area of mountains and solitary hills (Inselbergs), the area of Nubian sediments (Nubian sediments), and the area of valley deposits. The third terrain unit included three subunits: the Cretaceous sedimentary area, the Green Nile sedimentary area, and the Sixth Cataract area. The fourth terrain unit included two subunits: the area of gravel faces above alluvial fans and the area of mountains and rocky desert. Thus, the total number of subunits becomes eleven geomorphological units. From these geomorphological units, the main geomorphological phenomena were distinguished that can be relied upon in determining the specific spatial tourism specialization, such as the main valleys, the gorge, and the plateau, for example.

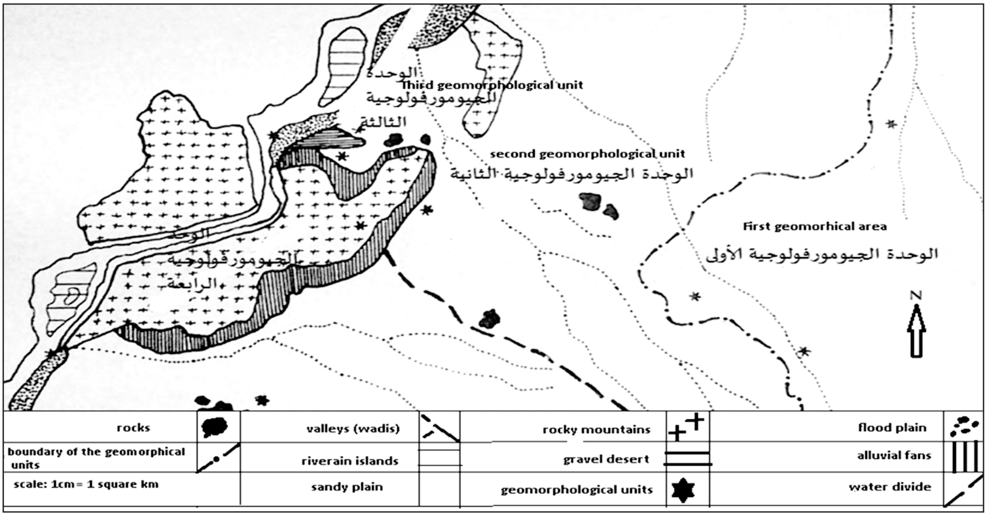
The physical components of tourism in the Sabaloqa region:

The general natural perspective of the Sabaloqa region (Figure 3) shows that it is a distinct geological and geomorphological unit, almost isolated from its general geographical surroundings where the Nile River penetrates it distinctly. The bedrock rocks are considered the oldest in the region, dating back to the Precambrian period. They are divided into ancient bedrocks such as ancient granite, gneiss, and migmatite, and modern bedrocks such as basalt, lower rhyolite, higher rhyolite, and agnambrite. As for the Nubian sandstone formations, they include sandstone, mudstone, and kanglomerite. The area is surrounded by Umm Marahik Mountain, which is bordered on the eastern and northeastern sides by exposed bedrocks. These rocks also appear from the western side of this mountain along its borders with the Nile River. As for surface sediments, they include the sediments of floodplains and flood basins and consist of silt, clay, sand, aeolian sediments, and flood fans.

The geomorphology of the Sabaloqa region (Figure 4) is represented by plain areas, isolated mountains (Inselebergs) hills, different patterns of surface drainage, and flood fans. The plain areas include both the Nile River floodplain and the plain extending from the east to the west of the region. As for the Nile floodplain, it is a narrow plain that expands as we head north, and its maximum width reaches 5 km in the Hajar al-Bashir area. Sand and clay deposits are abundant in the second plain, which extends from east to west, and gravel deposits and rock fragments are widespread. It is also home to solitary mountains and hills, such as Mount Babados, Mount Al-Salik, Mount Qari, and Mount Umm Marahik, as well as valleys such as Abu Jadad, Al-Salik, Al-Saqai, and Al-Mija.

Figure (3): Geographical distribution and topographic classification of seasonal valleys in the Sabaloqa region

Figure 4: The main geomorphological units of the Sabaloqa region

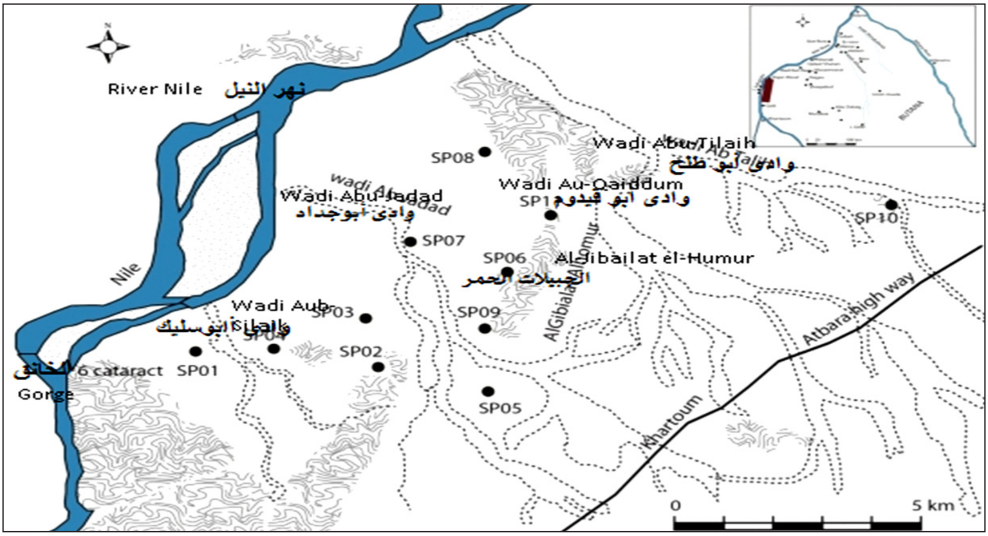


Source: Field work, satellite image 1983, Almond and Ahmed1993

The region slopes from the east and northeast to the west in the direction of the Nile. In the eastern and northern parts, the area rises to 462 m. The surface gradually descends to reach an altitude of 396 m in the central area. This gradient decreases until the Nile flood plain. It rises in the plateau area, which has the highest elevation (500 m) above the level of the Nile River.

The valleys in the Sabaloqa region (Figure 5) follow the natural slope of the land, as well as the direction of the contortions, rock formations, and areas of cracks and breaks that permeate the plateau and descend towards the Nile. The Nile River represents the permanent water source in the region, while the various valleys represent seasonal sources that are only filled with water when heavy rains fall, and many of them do not reach the Nile River. Accordingly, the seasonal valleys in the Sabaloqa region can be divided into two main parts. The first section includes the eastern valleys that descend according to the topography of the region and the water divide resulting from the presence of the plateau and the extension of the Sablouqa waterfall. It includes the valleys of Abu Qaydoum in the north, Abu Jadad in the center, Abu Sulayk in the south, and the valleys of Al-Miga and Al-Duma. The second section includes the western valleys that descend from the plateau towards the Nile during the flood season, and they are short and fast-flowing. Examples include the valleys of Saqqa, Al-Shulluk, Al-Sada, and Wadi Musa.

Figure 5: Valleys of the Sabaloqa area



The eastern valleys include the valleys of Abu Jadad, Abu Qaydoum, Abu Al-Salik, Al-Mija, and Al-Duma. They represent the most important drainage units in the region related to bedrock. They also represent transverse drainage systems parallel to each other. It slopes gently from east to west, following the general slope of the Earth's surface and the inclination of the layers, and its courses are intersected by systems of dividers, dams, and isolated rocky hills such as the Babdos, Qarn al-Taybeh, and Faraq al-Sarij hills. It is characterized by a tree water drainage system. These valleys remain dry for nine months, and when they begin to flow, their water flow is intermittent, and then their flow continues when rain increases and falls in large quantities. Wadi Abu Qaydum is considered the most important drainage valley in the north of the region (Figure 4). It descends at a narrow angle from the southeast to the northwest, with a length of 27 kilometers and an area of 48.12 km2, to empty into the Nile River. The number of its tributaries is 32. Abu Jeddad Valley is also considered one of the most important valleys in the center of the region (Figure 4). It extends from the southeast to the northwest towards the Nile, with a length of 25 km and an area of 52.2% square kilometers (Figure 4). It extends in the form of a wide, gently sloping plain, thus being a semi-erosive plain fed by 57 tributaries. It shows a greater drainage capacity than other valleys when compared to them, and the tributaries are characterized by shortness and straightness, as they cut into areas of cracks and breaks in granite, micagranite, and gneiss rocks. Wadi Abu Al-Salik is the most important drainage valley in the south of the region (Figure 4). Its length is about 17.5 kilometers, and its tributaries are 18, which are abundant in its upper reaches. Its water collection area represents a flat area covered by sand and gravel deposits. The valley is dry most days of the year, and is only filled with water when it rains, as it is characterized by intermittent flow in the lower parts of it. Its lowest point reaches 397 meters near the floodplain. The soil of this valley consists of silt (26%), clay (26%), and sand (48%).

The Sabaloqa region is characterized by the presence of a volcanic plateau that rises more than 500 meters above the level of the Nile River and from it several valleys descend towards the Nile, including Wadi Musa, Wadi Al-Saqai, Wadi Al-Shaluk, and Wadi Al-Sada. They are small valleys in length compared to the eastern valleys. They are also characterized by their shortness, straightness, and lack of branching, as they represent seasonal flow systems that are usually filled with alluvial and sandy deposits, often ending in a delta composed of silt, sand, and silt. Its length ranges from 2 to 3 km, and there is evidence of blocks, rock ledges, and cliffs reaching a height of between 50-100 meters. Rock fragments cover the upper reaches of these valleys and consist of loose boulder deposits, gravel, and coarse sand. Large rock blocks also appear on its sides in its upper reaches, as is the case in Wadi Koranda and Wadi Al-Saqqa. Wadi Al-Saqqa descends from the Sabaloqa Hills towards the Nile in a length of approximately 85 kilometers. The tributaries appear in a clear straight line, controlled by the topography of the region and the Umm Marahik fault system. This valley ends with a delta in the floodplain area with a length of up to 10 km, represented by sand, clay and silt deposits, and alluvial deposits appear up to a depth of 1.5 metres. Wadi Al-Saqqa appears as a seasonal drainage system with an area of 192.5 square kilometers. The basin fills when it rains for a period of no less than four months, as it is considered one of the sources of drinking water for the residents of the region. Trees and grass also grow on its sides and appear greener as we head toward the Nile.

As for the deposits of alluvial fans through which water was pushed from the tops of the mountains and highlands to the bottoms of the valleys, they are found in the floodplain area west of the Musikatab area, near the Nile River. They spread in the form of surface covers that take the shape of cones or fans, where the tip of the cone or fan indicates the direction from which the sediments come. Its base is between 26 and 30 meters long, as is the case in Wadi Abu Jadad and it slopes in the direction of the lower streams of the valley, where Wadi Abu Qaydum passes at its left end. It is characterized by the asymmetric grains due to the small amount of water that helps in the gradual distribution process and the varying shapes and sizes of its sediments, which consist of fragments of granite rocks and quartz pebbles. These valleys and seasonal watercourses helped form alluvial fans, such as the wide flood fans of Wadi Al-Saqqa, west of the Al-Kajina area.

The Nile River represents the most important permanent drainage unit, as it flows from south to north, and all the waters of the region drain into it (Figures 3, 4 and 5). In its flow, the Nile penetrates the aglomerite layer after completely denuding the Nubian sandstone layer until it reaches the plateau area. It extends for 40 km from Al-Jili in the south to Wad Banga in the north in an oval shape. Its true image appears after Royan Island, 12 km downstream. Its ability to sculpt has increased, which led to the formation of intermittent islands to its north as a result of the change in the course, such as Sangti Island. To the south of the waterfall, the islands are sedimentary, such as Al-

Ruyan Island. The gondola (waterfall) in this area creates bends in the river's course and its sides are surrounded by rocks of various types. The waterfall area consists of an extension of the plateau and is close to the volcano crater, where there are various rock masses.

The Sabaloqa area is famous for the flat-topped sedimentary mountain Umm Marahik, where Nubian sandstone rocks with a stratified composition were deposited over the bedrock in the Cretaceous period as a result of sedimentation processes. The region has been exposed to fault systems, the most important of which is the Umm Marahik fault. The Sabaloqa area is also famous for the annular dam, which is a magma rock that came out after the eruptions. The dam faces north-east of Al-Jubailat Al-Hamar and towards the east in Jabal Umm Marahik, and its rocks on the surface are formed in the form of a ring column with a thickness of 15 meters. This dam was displaced in Al-Jubailat Al-Hamar as a result of the Umm Marahik Fault. Micagranite rocks are also found in the form of low hills of red or pink color with large crystals of quartz and feldspar in a relatively smooth ground in the northern region. In the eastern and western regions of the tongue, there are intermittent rocks. The annular dam was formed after the tectonic movement and was given that name. An annular dam that surrounds the volcanic rocks on the plateau and the tongue until the Jubailat Al-Hammar has been subjected to weathering and erosion. The plateau is surrounded by some mountains, solitary hills and flood fans. Alluvial formations also emerged from the valleys that intersect the plateau, and these valleys intertwined with each other to form a consistent band around the plateau. Sandy and gravel deposits of Nubian sandstone rocks and rock fragments are found at the feet of the hills.

The region is characterized by a dry and semi-arid tropical climate. Temperatures reach their highest monthly levels during April, May and June, and the weather remains dry until the end of June. Then temperatures begin to drop in July and August due to humid southwesterly winds. By mid-September, a transitional period towards summer begins, and another short period begins with high temperatures exceeding 40 degrees Celsius. The lowest average monthly temperatures reach in January, with December, January and February considered the lowest hot months. Winter comes in mid-November and continues until March. The location of the region within a hot semi-desert climate and the low and fluctuating rainfall have led to a variation in its quantity from year to year and from month to month, as it is absent in December, January, February and March, while its quantities increase in the months of August and September, followed by the months of October, June and July. August is considered the rainiest month, and small amounts may fall in October, not exceeding 25 mm. The region is dominated by cold, dry northeastern winds in the winter period and humid southwestern winds in the rainy summer period from June to September. August is considered the humidest month, and the amount of evaporation is highest in April and lowest in the rainy season, with humidity also rising.

As for the vegetation, it is semi-desert annual and spiny plants that belong to the Acacia genus, and annual grassland plants with some perennial trees, as their presence is limited to valleys and low-lying areas. The vegetation cover in the Sabaloqa area varies in density, greenness, and type from one place to another depending on the type of soil, water, and topography of the area. In the loamy clay soil areas on the Nile strip, sidr, acacia, and willow, tamarisk, and palm trees prevail. As for the sandy clay soil, trees of syal, katar, sidr, and tandab grow, and grasses and weeds prevail, most of which are seasonal, and trees grow in the valleys and depressions. The ground cover that prevails around this soil is colocynth, anthracnose, eucalyptus, and tumbleweed. As for the soil of the stony lands, which are covered with gravel and stones, it has little vegetation cover, as sidr, tandab, sammar, aspen, and sandalwood trees grow in it.

The Qualitative spatial tourism specialization model:

1- A forward:

The research shows that the Sabaloqa area possesses diverse natural capabilities that enable it to specialize in tourism. The diversity of the natural components and the geographical location of the region will be discussed in order to highlight them as two pillars of the tourism development of the region within the framework of the qualitative spatial tourism specialization model.

The richness and diversity of the natural landscape provides a tourism infrastructure that can be exploited easily. Mountain tourism in the Alps region depends on exploiting the mountains with their natural components and inherited characteristics to create the appropriate infrastructure for this, so that they have become a tourist attraction for skiing in the winter period, as well as utilizing them as parks in the spring and summer periods. In many mountainous regions of the world, such as the Asir region in the Kingdom of Saudi Arabia, many studies indicate this (Supreme Commission for Tourism, Kingdom of Saudi Arabia 2003). The weather and economic and social aspects greatly affect recreation in the greater Khartoum region (Mohamed Khair 2009). Although the Sabaloqa region differs in its climatic characteristics from the Alpine region and other similar mountainous regions, the characteristics of its desert climate are considered a basic pillar of desert tourism, which is found in many areas. Countries of the world located in dry environments. In Yemen, Algeria and Tunisia, tourists come to visit natural desert landmarks despite the difficult climatic conditions, but the availability of infrastructure for desert tourism in these countries has overcome these difficulties. Jebel Marra's climate is the best type of climate that attracts tourists despite its location in a semi-arid region, and the winter season ranked first to attract tourists (Alredaisy, 2003). The fact that the Sabaloqa region enjoys a short rainy period and is exposed to humid southwesterly winds during the period from June to August may be a factor mitigating the difficult desert climate conditions. The geographical and climatic location that determines the ease or difficulty of tourism investment has been exceeded in many of the famous tourist areas of the world. An example of this is the Luxor region in Egypt, which is hot and dry in climate, and yet it is one of the most attractive regions in the world for tourists.

The richness of the Sabaloqa region with wide valleys, as well as mountain valleys and multiple volcanic phenomena is a strong attraction like it and many other regions of the world. Another attractive geographical phenomenon is the Nile River, with its distinct characteristics that are only found in this part of the course from source to mouth. The existence of the Sixth Cataract and its extreme narrowness may be widely known inside and outside Sudan. The distinction of a region with such a distinctive geographical phenomenon is considered a major attraction factor, as is the case in Niagara Falls and the Bosphorus Strait, which tourist statistical data confirms are among the most attractive regions for tourists in the world (UNWTO 2009).

The geographical location of the Sabaloqa region has an important role in attracting tourism due to its proximity to the capital of Sudan, Khartoum, which is considered a factor that attracts labor, as is the case in the Red Sea region, as tourism provides job opportunities for workers in the rural areas adjacent to tourist sites, whether by absorbing them in direct tourism work or through Establishing their own businesses, which enables the integration of the rural agricultural livelihood economy into the market economy, which increases the demand that leads to the creation of added value for agricultural and animal products found in rural areas through the establishment of light manufacturing industries to serve tourism purposes, and then expand the circle of tourism culture and spread it among Citizens, which has a positive impact on production, productivity and social harmony (Mohamed 2008). Although the rural community of the Sabaloqa region does not have the qualifications required for tourism work, the

Red Sea experience can help this community benefit from tourism activity.

But the Sabaloqa area's lack of attractive infrastructure may be considered a repulsive factor at the present time, like many areas in the world. In the Taiz region in Yemen, the lack of tourist services and facilities represents the most important problems facing tourism in the region (Al-Najjar 2005), as well as in the Jebel Marra region (Al-Rasheed 2003). Most parts of Sudan clearly lack tourism services and infrastructure, and this is clearly linked to issues of economic development in Sudan (Hayati 1997). But there are other regions in the world that do not have the required infrastructure, but they attract many tourists because of the efforts made in developing appropriate plans to achieve this goal, and this is what this paper will seek to achieve in developing the proposed geographical model for developing mountain tourism in the Sabaloqa region.

2- The components of the proposed model:

The study area possesses the diverse natural components necessary for tourism, which include the distinguished geographical location close to the capital, Khartoum, the large area, multiple geomorphological characteristics, climate, and the Nile River. With the aim of developing the region touristically, based on its aforementioned natural components, and after dividing the region into four large geomorphological units on a drawing scale of 1:250,000 (Al-Rudaisi et al. 2015) (Figure 5), as previously mentioned (the section on field work), in order to emphasize the possibility of spatial tourism specialization, qualitative, which forms the basis of the proposed geographic model (Figure 6). The main geomorphological phenomena in each unit have been distinguished so that they can be considered specialized tourist places that provide a type of specialized tourism, as follows:

A - In the first geomorphological unit, the following areas were distinguished:

1. Rocky hills area (scattered mountains)
2. The Eastern Valleys (Abu Jadad, Abu Qaydoum, Abu Al-Salik, and others)
3. Sand dune area.

B- In the second geomorphological unit, the following areas were distinguished:

1. The region of solitary mountains and hills (scattered mountainous regions)
2. Nubian sandstone deposits area (plain area)
3. Valley deposits area.

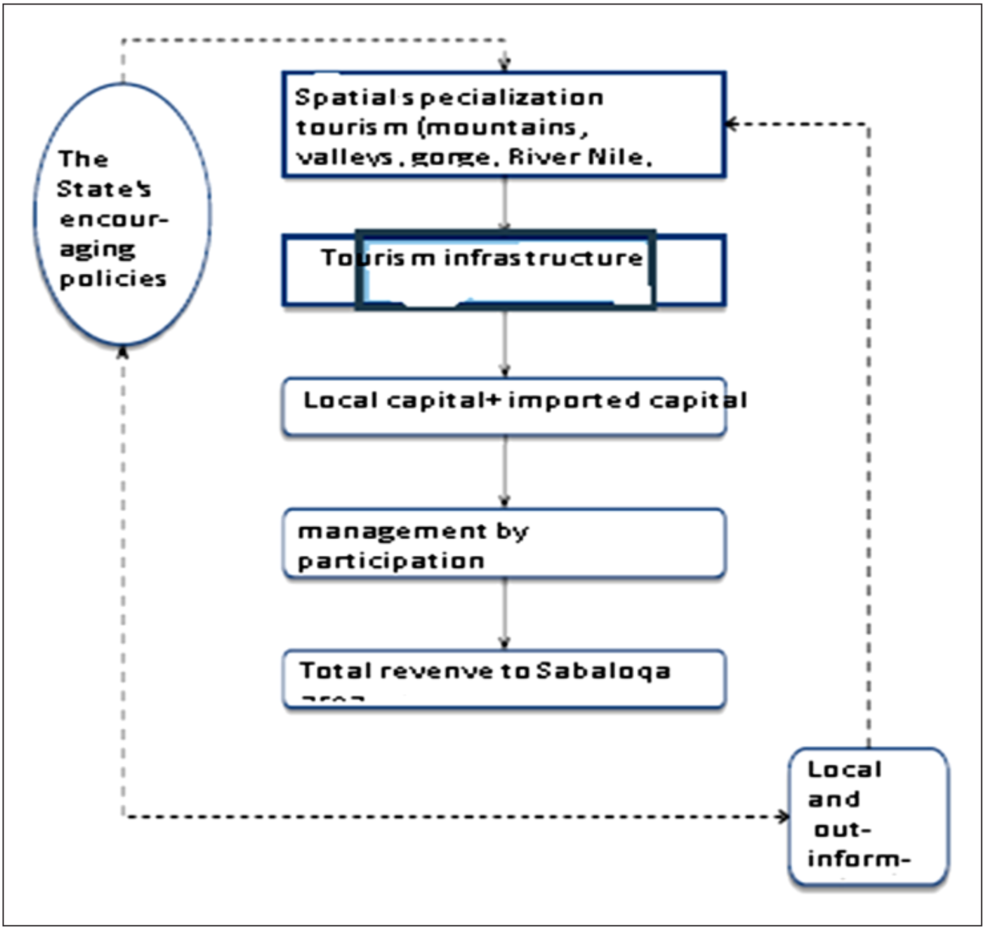
C- In the third geomorphological unit, the following areas were distinguished:

1. Green Nile region (banks of the Nile)
2. Flood fan zone (at the feet of mountains and scattered hills)

D- In the fourth geomorphological unit, the following areas were distinguished:

1. The plateau area
2. Western Valleys (Wadi Musa, Shilluk, Sada, and others)
3. Waterfall area
4. The main course of the Nile River.

Figure (6): A proposed model for developing mountain tourism in the Sabaloqa region



Following the determining the specific tourism spatial specialization, comes the stage of providing the infrastructure for each type of specialized place. In addition to the usual infrastructure for tourist areas that must be provided by the state due to its high cost, and it includes roads and accompanying services such as hotels, hostels, water, electricity, roads, security, and others, there is a need to provide infrastructure from local materials, which include mountain stones, sand, gravel, and agricultural products such as Bamboo mats, cannas, and others. In many famous tourist areas around the world, their fame has come from their excellence in using available local materials that can be used to improve scientific methods, and benefiting from local experts in the field of decoration and Sudanese heritage to reflect their attractive artistic aspects.

Specific tourism spatial specialization, and the construction of infrastructure for the Sabaloqa region, can be achieved by taking advantage of local capital, and it does not necessarily have to be from within the region, although there is a priority for that. There are a large number of travel and tourism agencies and tourism companies that have experience in this field. They can be grouped and functionally classified and each sub-group assigned to work in a specific type of tourism (river, mountain, valley tourism, garden and park tourism). Since there is a recommendation to benefit from local materials to build infrastructure, the contribution of local capital can be effective and highly responsive. As for foreign capital, it can be used to build specialized and high-financial infrastructure, such as hotels and wild parks whose animals are imported from outside the region, in addition to the state's participation in providing road infrastructure, water networks, and accompanying services. This requires ensuring the availability of tourists throughout the year, especially foreign ones. In this aspect, regulations and systems must be enacted to encourage tourism investment in Sudan in general and waive the state's share

For a limited period called the investment grace period, after which the state begins to reap returns after establishing the tourism infrastructure and recovering companies.

It invested an estimated portion of its capital spent on this structure, and reconsidered the laws of land ownership.

Figure (7): The waterfall (gorge) area and a model of operating tourist boats

In order to ensure that the region and its citizens benefit from tourism, the element of participation in management is considered an essential element. This can be achieved by establishing joint departments in each specialized tourism project between local (or foreign) shareholders and educated local cadres from the citizens of the region, as indicated by the results of the study (24.6% have completed the secondary stage and 4.7% have completed the university stage), after training them on the job. Tourist. Simple workers from the region's population can also be involved with a representative on the board of directors in each specialized project. Many residents of the region can gain experience in administrative work through field practice through direct supervision of some project tasks and technical consultations with the relevant authorities. This does not prevent the holding of specialized training courses in the arts of tourism work.

To achieve all the mentioned stages of developing the Sabaloqa region in the field of tourism work, encouraging policies must be available from the state and the internal and external media. In tourism promotion policies, it is necessary to facilitate procedures and transparency in dealing with investors, and to reduce or eliminate taxes when necessary, especially in the stage of establishing infrastructure. The external media is one of the most important elements for the success of tourism work at the present time. Tourism promotional services are not available in Sudan, as well as the amount of published data to inform citizens of tourism sites is insufficient, and the ministries do not perform their role efficiently in spreading tourism awareness due to the lack of the necessary funding from the state, the neglect of qualification and training for human cadres, and the failure to develop a fixed strategy for tourism promotion (Othman 2006, Al-Fahl (2010). Also, the type of programs shown on Sudan TV to introduce tourist sites is insufficient (Al-Tijani 2010). The state can issue tourist brochures about the study area in the media, and benefit from media attachés in Sudanese embassies abroad to introduce the region in particular, and facilitate Internet services for all parts of Sudan so that Sudanese can visit the region, as well as for users of social media networks, and others. The tourist is the main factor in the tourism movement, and therefore it is necessary to increase awareness of the importance of integrated information about tourists in terms of needs, desires and tastes that are reflected in their behaviour. The tourist's behavior also affects the future of tourism in terms of preserving the brand of the tourist facility and ensuring the continued flow of tourists to the tourist area. (Salem 2007).

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دار آريثيريا للنشر والتوزيع
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